CERTIFICATE

This is to certify that this dissertation entitled **"FUNCTIONAL AND RADIOLOGICAL OUTCOME IN LOW DYSPLASTIC SPONDYLOLISTHESIS - A CASE SERIES"** is a bonafide record of work done by Dr. VIJAY ANAND. H. S M. B. B. S., D. Orth. under my guidance and supervision in the Department of Spinal Disorders Surgery unit of Orthopedic Surgery, Christian Medical College and Hospital, Vellore during the period of 2008 – 2010.

This dissertation is submitted to Tamil Nadu Dr. M. G. R. Medical University, Chennai towards partial fulfillment of the regulations for the award of Master of Surgery (Branch –II) Orthopaedic Surgery.

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INTRODUCTION

Spondylolisthesis and its management has been evolving and highly debated topic among leading Orthopedicians and Neurosurgeons.

The term **Spondylolisthesis** was first used by **Killian** in 1854, derived from Greek word "**Spondylos**" (vertebra) and **Olisthesis** (slipping)[1 2 3]. The forward slippage of one vertebra on its caudal segment placing pressure on the nerve roots, disruption in normal lumbar lordosis and biomechanics of the lumbosacral spine.

Spondylolisthesis is easily recognized, yet difference of opinion persists over its natural history and preferred treatment[4]. Disparate pathologic conditions produce spondylolisthesis because of the common morphology and biomechanical forces applied to the lumbosacral junction.[4]

Dysplastic spondylolisthesis is congenital dysplasia of upper sacrum or neural arch of L5.[5] Due to dysplasia, there is insufficient strength to withstand the forward thrust and the last free lumbar vertebra gradually slips forward on the one below. Pars interarticularis either elongates or lysis occurs.[5]

Fredrickson revealed 66% were asymptomatic. Dysplastic variety is more common in adolescence, but symptomatic in adulthood.[6] It is more common in females, and manifests in adulthood more often than childhood.

The clinical features and natural course of listhesis is extremely variable. Surgery was offered to patients who had disabling back pain, postural and gait disturbances. So also it's indicated in patients with radicular pain with neurological deficits. Definitive treatment was planned after confirming the diagnosis of listhesis with radiographs, Computer Tomography (CT) scans and Magnetic Resonance Imaging (MRI).

A variety of surgical approaches have been described to achieve neural decompression, spinal stabilization and deformity correction in patients with a low-grade Isthmic spondylolisthesis. [7] Isolated posterior decompression and posterolateral fusion achieves direct decompression of the neural elements and stability of motion segment, but it does not reconstruct the anterior column and may exacerbate the kyphosis.[7]Anterior lumbar interbody fusion (ALIF) reconstructs the anterior column, however direct decompression of the exiting nerve roots, is not possible. Anterior approach endangers major vascular structures and the hypogastric nerve plexus. Posterior lumbar interbody fusion (PLIF) exploits the benefits of combined anterior and posterior procedures which reconstructs the anterior column through posterior approach. [7]

The primary objective of this study is to assess the surgical outcome and evaluate the radiographic fusion and clinical outcomes of adults with low-grade dysplastic spondylolisthesis who underwent posterior lumbar interbody fusion surgery.

HISTORICAL REVIEW

HERBINAUX (1782), a Belgian obstetrician first noted a bony protuberance that hindered delivery[8 9].

ROKITANSKY (18th Century) First described lesion as a pathological entity "*spondylolisthetic pelvis*"[10].

*KILIAN i*n (1854) coined the term spondylolisthesis. [1 2 3]

ROBERT ZU KOBLENZ (1855) localized the defect in pars interarticularis but misidentified it as a subluxation of the facets.

NEUGEBAUER (1888)[11] First classified listhesis as 2 types after examining European cadaveric specimen recognized the congenital defect of pars interarticularis.

HIBBS & ALBEE [12] (1911) separately published their initial work on posterior spinal fusion.

CAPENER[13] **(**1932) separated patients based on pars interarticularis defect.

Class 1 – defect in pars interarticularis.

Class2 – intact but elongated pars interarticularis.

MEYERIDING[14] **(**1932) assigned grade to the slippage based on anteroposterior diameter of sacrum.

MERCER (1936) [12] theorized that ideal operation for stabilization of spine was interbody fusion.

CLOWARD[15] (1943) performed his first planned posterior lumbar interbody fusion (PLIF).

TAILLARD[16] (1954) measured percentage of slipping based on anterior displacement of vertebra in relation to sacrum "Degree of spondylolisthesis".

WILTSE, NEWMAN & MACNAB[5] 1976 classified spondylolisthesis as 5 distinct types.

ROY-CAMILLE[17] (1986) introduced pedicle screw fixation for posterior stabilization .

EDWARD[18] (1985) developed the concept of gradual instrumental reduction by applying 3 corrective forces *distraction, posterior translation, sacral fixation*.

INCIDENCE & PREVALENCE

Several epidemiological studies have showed that the incidence of symptomatic listhesis in Caucasian populations varies from 4 %to 6%. [19 20]Dysplastic type forms 14% to 21% of all spondylolisthesis. [6] Defects of this nature are common to all races. Instances have been found all over Europe, among the Bantu (Shore), in Japanese (Hasebe), in American aborigines (Congdon), in Eskimos (Stewart), and in Americans and American Negroes (Willis). [21]

WILTSE[22] found incidence of spondylolisthesis to be 5% in childhood and 6-7% in adulthood. In their study male to female ratio was 2:1.

FORD and GOODMAN[23] reported 7% incidence of spondylolisthesis. Prevalence stabilizes after adulthood. Later occurrences are of acquired degenerative etiology and not developmental in patients more than 50 years.

VIRTA[24] showed 7.7 % prevalence in men and 4.6% in woman. Male to female ratio of adult Isthmic spondylolisthesis is 2:1.

DANDY & SHANNON[25] 67% of their patients were woman with developmental spondylolisthesis. Lytic type of spondylolisthesis increases from less than 1% in children 5 years of age to 4.5% in children of 7 years age. Remaining 0.8%- 1% increase in spondylolisthesis occurs between the ages of 11 to 16 years, which can be attributed to athletic activity in this age group.

EISENSTEIN [26] [27] reported that the prevalence rate is high in certain ethnic groups, such as Yukon Eskimos as high as 50% (13% children + 54% adults). This remarkably high incidence is attributed to both genetic and environmental factors.

Associated conditions:-

1. Spina bifida occulta commonly accompanies isthmic defects with reported incidence of 24-70%. *WILTSE* stated that spina bifida occulta occurred thirteen times more often in patients with spondylolysis[28] than those without that lesion and *TAILLARD* reported 42% incidence in his study group. It also occurs in approximately 35% of patients with dysplastic listhesis.[20]

2. Scoliosis occurs in 5-7% of patients with spondylolisthesis and spondylolysis, which may be degenerative in origin and often corrects with fixation and fusion of segment. Larger curves of spine may be torsional with structural components requiring instrumentation and correction simultaneously.

BIOMECHANICS

The structure of the lumbar spine is such that, in the erect posture, produces a downward and forward thrust to the lower lumbar vertebra. Vertical loading produces stress on the neural arch, particularly in the isthmus. Stabilizing factors in normal spine at L5-S1 junction are

1. Intervertebral disc – concentric structure of annulus fibrosis and reinforced anteriorly and posteriorly by Anterior Longitudinal Ligament and Posterior longitudinal ligament. [29]
2. Intact Ligamentum Flavum –causes an increased degree of extension at the L4–L5 leading to retrolisthesis of L4. [30]
3. Articular capsules.
4. Supraspinous and interspinous ligaments.
5. Inferior facet of L5 articulates with superior facets of S1 and enhances lateral and posterior stability.

KUMMER and *BERGMARK* have stated in their fundamental studies that shear forces occur in every segment of the vertebral column due to the action of oblique back musculature.[31] The shear forces are pronounced in the lumbosacral transition because the intervertebral discs are oriented obliquely. The pathomechanism at the lumbosacral joint can be understood only after knowing these shear forces which act under normal and compensated physiological conditions. The shear forces in the lumbosacral joint can be compensated by the following mechanism.

1. Orientation and structure of the facet joints.
2. Integrity of the facet joints
3. Active compression by the posterior musculature
4. The integrity of the Intervertebral disc

Biomechanically, the interbody fusion is particularly appealing because 80% of weight-bearing occurs through the anterior column across the disc.[32] The line of action of the upper body weight passes anterior to the lowest lumbar segments [vector G][33] (Figure 1).The orientation of erector spinae muscles [vector M] maintain the vertical posture of the spine [34], with the facet joint as fulcrum. The muscle force acts over a short lever arm of about 5 cm. The resultant force [vector R] is the vector sum of G and M, actual force applied through the center of the lumbosacral disc. [31]

The vector R is not directed perpendicular to the vertebral end-plates but instead it strikes these from a cranial, ventral direction. According to Pauwels's classic study ,the direction of the force is mirrored in the [35]trabeculae of the lumbar spine. A sagittal section of a lumbar vertebra demonstrates bony trabaculae perpendicular to the end-plates **(**Figure 2**)** and not oriented along the slanted direction of R. The reason for this discrepancy is the reorientation of the force vectors through the arrangement of the lumbar facet joints. Due to the hinge action of the facet joints, R is broken down to two components, S and L (Figure 3).

The vector L (Figure 2) represents the longitudinal, compressive component acting perpendicular to the adjoining end-plates L5 and S1. That is, vector L is the actual force experienced by the ventral vertebral column-the vertebral bodies, the discs, and the end plates. The direction of L determines the observed perpendicular direction of the bony trabaculae.

The vector S (Figure 3) represents the ventrally directed shear component, which tends to cause ventral displacement of the cranial vertebral body. In normal healthy individuals, a counteracting force S’ of equal strength but opposite direction is provided by the dorsal structures, primarily by the facet joints and secondarily by the ligament. [33]

KUMMER and PULF [36] demonstrated that dorsal distraction force leads to an increase in the shear forces and counter the physiologic tension band principle of the vertebral column. Additionally, alteration of the normal lever arm also leads to an absolute increase of shear forces.

Pedicle screw fixation instrumentation (Figure 4) is advocated as a measure to attain rigid fixation while interbody graft is incorporating, thereby enhancing union.[37] Fixation may also reduce the risk of deformity progression due to wide decompression and postoperative back pain, thereby encouraging early ambulation. [38-43] Biomechanically, pedicle screws achieve three-column fixation with a stronger grip force than other posterior fixation systems.[44-47] In comparison to hook–rod and wire systems, transpedicular technique requires fixation of fewer motion segments, thus preserving normal adjacent segments. This may reduce the risk of postoperative mechanical pains. [17 39 47-49] Moreover, pedicle screws do not require intact posterior elements or canal intrusion for placement. [16 19-2217 42 48 49] Despite the potential risks of neural damage, dural leak, vascular injury, and possibly increased infection associated with these devices, larger series have demonstrated their safety.[39 42 49-58]

ETIOPATHOGENESIS & PATHOANATOMY

The etiology of spondylolisthesis has been a topic of debate.

RAMBAUND & RENAULT (1864)[59] they related the defect to failure of two separate ossification centers, resulting in spondylolytic defect.

WILLIS (1931) [60] disagreed with this hypothesis suggesting the defect was the result of anomalous pars interarticularis and that trauma played a secondary role.

HITCHCOCK (1940)[21]working on infant cadavers suggested it as birth fracture and he said that hyper flexion at the time of delivery was the cause of defect.

WILTSE (1957) [5] theorized the lesion of pars interarticularis results from dissolution of continuity of bone due to congenital weakness at this point in cartilaginous model of the arch of the affected vertebra. He went on to say that the defect was of varying expressibility and dissolution remained an enigma.

LOGROSCINO (2001) [60]The defect in pars interarticularis of L5 is produced by “pinching” compression between upper superior articular process of sacrum and inferior articular process of L4 eroding the pars interarticularis.

The etiology now generally accepted as mulitfactorial and they are:

1. Hereditary dysplasia
2. Bio-mechanical stresses
3. Traumatic events

1. <u>Hereditary Dysplasia</u>

WILTSE (1957) **-** there is a recessive pattern of inheritance with varying expressivity that is not sex linked. [5]

DAVIS & SCOTT **(**1979) [8]suggested autosomal dominance with reduced penetrance or mulitfactorial pattern of inheritance.

Heredity plays major role in developmental dysplastic spondylolisthesis. Listhesis is severe and appearing during adolescent growth spurt. True congenital spondylolisthesis is rare.[21] There is congenital dysplasia of the “**bony hook”** (Figure 5) consisting of a pedicle, pars interarticularis, inferior articular facet of L5 and the “**catch”** consists of a normal size well positioned sacral facet. Once the structural continuity of bony hook is deficient, mechanical stress and the patients' gravity line influence the development of slip. In dysplastic spondylolisthesis multiple anomalies of the lower lumbar spine may be present depending on age of patients, and the time when x-rays are taken. Difference between 2 types of dysplastic anomalies

Low Dysplastic

- Upper end plate of S1 almost normal.
- Upper end plate of S1 & lower end plate of L5 are not parallel.
- Pars interarticularis may/may not show lysis.
- Lesser degree of Lumbosacral angle compared to high dysplastic[61]

High Dysplastic

- S1 upper end plate grossly rounded.
- Posterior vertebral body L5 parallel to anterior vertebral body of S1.
- Rudimentary L5-S1 disc space with facet dysplasia
- Lumbar Index less than 80.[62]

- Higher degree Lumbosacral angle.[61]

2. <u>Bio-Mechanical</u>

In flexion, pull is applied on to spinous process. The lower part of pars interarticularis is subjected to compression and upper portion is subjected to distraction forces. Conversely in extension, resistance is applied to the inferior articular process. Distraction forces acting on lower portion of pars interarticularis and compression on upper portion of pars interarticularis. Repeated compression – distraction in vertical loading leads to stress fracture of pars interarticularis and defective “bony hook” and “catch” system[63]. Instability leads to facet joint and ligamentum flavum hypertrophy to prevent further slip. Hypertrophy then leads to spinal stenosis.

Predisposing factors as per *WILTSE* is active teenage boys in football and pole vaulting children. Young people are more likely to develop spondylolysis because they frequently engage in strenuous activities at a time, when their intervertebral discs are more elastic and their neural arches may not be completely ossified. [64]11% Female gymnasts have shown pars interarticularis fracture with or without slippage at L5 bilaterally [65].

The weakest link in immature spine with lysis during an anteroposterior shear load is the growth plate, between the cartilaginous and osseous end plates[66]. Surgeons may assess this lesion on MRI, thereby predicting the course of development and preventing progression of listhesis.

3. <u>Traumatic:</u>

Traumatic listhesis is rare. It occurs as a result of violent trauma to spine which results a disruption of facet joints and fracture of transverse process. The fracture occurring in early infancy or in childhood, it would account for the findings of union by fibrous tissue or cartilage, the development of a pseudoarthrosis, the absence of healing, and unilaterality.

NATURAL COURSE

Patient with developmental spondylolisthesis with lysis typically present for treatment earlier in life than patient with acquired spondylotic spondylolisthesis. In Newman's series, 34 of 66 patients had listhesis more than 50%, 29 patients without lysis experienced symptoms before 19 years of age. Listhesis more than 25% without lysis have relative compression of cauda equina.[67]

Depending on the degree of listhesis, location of dysplasia, the biomechanics of spine and the integrity of disc, the severity with which spondylolisthesis progresses is determined. If dysplasia is presented with spina bifida or deficient "bony hook" the spondylolisthesis is set to progress. As a consequence the entire spine gradually slips forward on sacrum once child start ambulating and stands with lumbar lordosis. Erect posture may aggravate the pars interarticularis fracture. The disc under increased stress many lead to early failure. The increased stress on posterior part of L5 lower plate and anterior part of upper plate of sacrum produces domed sacrum and trapezoidal L5 in growing child.

In very early stage there could be mild slip and intact disc and a bony hook, but later on dysplastic pars interarticularis elongates and eventually fractures. The amount of secondary bony deformity is dependent on the skeletal growth remaining and the degree of slip. As the listhesis progress neurology deteriorates until pars interarticularis defect occurs and then neural arch is decompressed. The neurology further deteriorates if slip worsens. Generally dysplastic spondylolisthesis worsens gradually.

In skeletal mature adult sacral end plate remains horizontal despite progressive spondylolisthesis. Eventually disc may fail after many years of increased stress, since growth is complete. Skeletal change described earlier doesn't occur.

CLINICAL FEATURES

Dysplastic patients may present with following

Symptoms

1. Hamstring tightness is the earliest one to present.
2. Low back pain with stiffness.
3. Associated radicular type of pain to the buttocks and occasionally the thigh.
4. Leg pain.
5. Awkward gait –severe slip more than 50% and spondylolisthesis without lysis.
6. Severe low back ache – spondylolisthesis without lysis.
7. Occasionally cosmetically prominent sacrum area.

Signs that are elicited

1. Hamstring spasm.
2. Waddling gait.
3. Increased lumbar lordosis.
4. Para spinal muscle spasm.
5. Diminished ankle jerk.
6. Decreased planter flexion power of the toes.
7. Diminished sensation and control of the bladder and rectal sphincter.

Low back pain is the most common symptom which typically starts with adolescent growth spurt. Listhesis is most common cause of low back ache in children, whereas most adolescents are asymptomatic. The relative importance of back and leg pain as presenting complaints and the relevance of objective neurological deficits vary widely in reported series. [68-72]

FREDRICKSON found none of the children in his series complained of pain during the development of defect[73]. *WILTSE & JAKSON* found slips progress between 10-15 years of age, few were symptomatic[74]. *SARASTE* long term follow up found L5 lysis with mean age of onset of symptoms was 19 years and radiographic diagnosis was made at age of 23 years. Although 91% of patients experienced some form of back pain, 55% complained of sciatica and disabling pain in 13%. The most common pain pattern was low back pain with dull aching pain in buttocks and posterior thigh. In the second pattern, pain radiating to lower extremities with little or no pain in back. This is typical of dysplastic listhesis suggesting root irritation.

All grades of listhesis give rise to local signs and hamstring spasm. Restricted straight leg raising test may be attributed to hamstring tightness.80% patients with hamstring spasm represents, either attempt by body to control unstable L5-S1 level or to rotate pelvis into more vertical position to help reestablish body's centre of gravity. To stand erect patients must compensate every degree of lumbosacral kyphosis, which is accomplished by tendency of iliopsoas and hamstrings to rotate the pelvis into more vertical position and arches throacolumbar spine to maximal lordosis. Interestingly patients with postoperative fusion needed 6-8 months to resolve spasm.

Step off is felt above the level of slip in grade 2 and above.

Lumbosacral kyphosis makes the iliac wings appear widened, with flattened buttocks, thus producing typical flat square pelvis, “sweetheart pelvis”.

Loss of trunk height is responsible for clinical signs of absent flank creases and cosmetically offensive belly in young patients.

Gait abnormalities characterized by waddling type with limited hip flexion, shortened stride length and wide base support. This gait is resultant of hamstring tightness, vertical tilting of pelvis, compensatory hyperlordosis and flexion deformity of hip and knees.

Radicular pain and varying root dysfunction roughly forms half the patients requiring surgery. Most patients with L5 radiculopathy in L5-S1 spondylolisthesis have subjective decrease in light touch sensation over dorsum of foot and mild weakness of extensor hallucis longus, correlating with L5 root irritation. Loss of bowel and bladder function due to sacral root involvement does not routinely appear as an indication for surgery. Some of the identified risk factors which potentially warrant surgery are:-

1. CLINICAL
   a. Age –earlier onset carries increased risk
   b. Greatest risk during adolescent growth spurt
   c. Sex –possible more in females
   d. Symptoms-children with repeated episode of back pain
   e. Deformity – postural deformity/gait abnormality
2. RADIOGRAPHIC
   a. Hyperlordosis exceeding 50^0 increases risk
   b. Degree of slippage –grade 2 and above
   c. Slip angle greater than 25^0
   d. Trapezoidal shape L5
   e. Rounded sacral endplate

f. Disc degeneration

CLASSIFICATIONS

Lumbosacral spondylolisthesis was initially classified in 1963 by Newman and Stone in their radiographic review of more than 300 patients. [75] Approximately half of these patients were described as having a “spondylolytic” form of spondylolisthesis. Subsequent classifications were developed by Wiltse et.al[5] (Table 1) and by Marchetti and Bartolozzi.[76] (Table 2 and Table 3) In terms of describing the severity of spondylolisthesis, the Meyerding scale is the most widely recognized method. In this scale, the severity is graded according to the relative extent of anterior translation of the cephalad vertebral body over its distal counterpart. Anterior translation of less than 25% as grade I, 25% to 49% as grade II, 50% to 74% as grade III, 75% to 99% as grade IV and 100% or greater as Grade V. This review addresses the topic of adult patients who present with a “low-grade” (Meyerding Grade 0, I, and II) spondylolisthesis.

Limitations of Wiltse classification:

1. Etiology not mentioned, rather based on mixture of etiology and topographic criteria
2. No mention regarding increasing trend of post surgical forms
3. Does not allow sufficiently precise, reproducible identification of all cases

<u>Dysplastic spondylolisthesis</u>

S1 or L5 usually show major congenital changes and pars interarticularis is poorly developed. It results from congenital dysplasia of upper end plate of S1 and neural arch of L5. It appears more common in girls than boys and has high familial tendency.

According to Marchetti and Bertolozzi[76], pathology is not present at birth. In dysplastic type the only congenital characteristic being high or low degree dysplasia. High dysplasia onsets during adolescence mostly located at L5-S1 and there is local kyphosis angulations. This type is progressive, and leads to severe instability. Low dysplasia has a slow progression and may be seen at higher levels; end plates of slipping vertebrae are parallel or have lordotic angulations [76-78].

<u>Isthmic spondylolisthesis</u>

Type A – disruption of Pars interarticularis due to stress fracture. Common in age group of 5 years to 50 years.

Type B – repeated micro fracture of pars interarticularis heals spontaneously.

Type C – results from acute fracture, invariably severe fracture of pars interarticularis.

<u>Degenerative spondylolisthesis</u>

Results from long standing intersegmental instability, with remodeling of articular process at the level of lesion. Multiple small compression fracture of inferior articular process of vertebra that slips forward also has been postulated. This lesion is 4 times more common in females than in males and 6 times more common at L4-L5 than at adjacent levels. Seen in elderly age group and does not slip more than33%.

Traumatic spondylolisthesis

Results from acute fracture of bony hook and disruption of facet joints. An isolated pars interarticularis fracture is not seen with this lesion.

Post Surgical spondylolisthesis

a) Direct cause – segmental instability due to wide laminectomy
b) Indirect cause -- one level above or below the interbody fusion created by surgery

Pathological spondylolisthesis

Rarely encountered, either from local or generalized bone disease. e.g.:- arthrogryphosis, Paget's, Albert's Schonberg Disease, Syphilitic bone disease.

RADIOLOGY

Many radiographic measurements have been proposed to evaluate the severity, associated changes, and progression of slip in spondylolisthesis.

Questionable slip is determined by ULLMAN SIGN, a line drawn on anterior surface of sacrum projected at or in front of anteroinferior angle of last lumbar body. If the line is intersected, displacement has occurred. NAPOLEON HAT SIGN indicates severe degree spondylolisthesis.

Typical X-ray features of DYSPLASTIC TYPE [62]

a. Par interarticularis defect. Both lytic and elongative type.
b. Facet dysplasia of the L5–S1 facet joints.
c. Rounding of the proximal sacral endplate.
d. Trapezoidal shape including anteroinferior elongation of L5.

e. Gross Lumbosacral kyphosis.

f. Evidence of spina bifida in the posterior elements of L5 and sacrum, including laminar defects.

Radiography that were taken in our patients for this study includes

1. Standing anteroposterior lumbosacral spine– to look for
    a. Pars interarticularis defect
        i. Unilateral
        ii. Bilateral
    b. Facet hypertrophy
    c. Associated anomalies such as spina bifida occulta
2. Ferguson - 30^0cephaloid directed AP –to assess
    a. Lumbosacral junction
    b. View of L5 transverse process
    c. Sacral Ala
    d. Relation between these structures
3. Standing neutral lateral – to look for
    a. Dysplasia L5/S1 (trapezoidal L5/dome shaped S1)
    b. Disc height
    c. Measurement of slip angle, degree of slip, angle of lumbar lordosis, sacrohorizontal angle, sacral inclination, wedging of listhetic vertebra.
4. Flexion – Extension lateral X-ray – for hyper mobility at listhesis or other levels in postoperative patients for translation at the fusion site to rule out pseudoarthrosis.

5. Oblique view- "Beheaded Scottish Terrier" representing superior articular process, with belt on the neck – due to break in pars interarticularis.

PERCENTAGE OF SAGITTAL TRANSLATION

It is important to know the preoperative, immediate postoperative and final follow up percentage of slip. Slip percentage assessment at immediate postoperative will indicate the degree of correction and the maintenance of correction by the final follow-up x-ray. It is highly important in high dysplastic and iatrogenic spondylolisthesis where instrumented reduction has been done.

Two principle methods of measuring degree of slip are used. One is MEYERDING method. This method divides superior surface of first sacral vertebra into 4 quarters (Figure 6) and assigned as grade I, II, III, IV and Vth grade – spondyloptosis.

Advantage

1. Simple.
2. Easy to estimate and interpret.
3. Easy to reproduce.
4. Less intra and interobserver variability.

Disadvantage – does not quantify numerically

TAILLARD'S [16] method is used to measure percentage of slipping and later popularized by LAURENT & OSTERMAN[79]. The forward displacement of the spondylolytic fifth lumbar vertebra in relation to the sacrum is measured as a percentage of the anteroposterior diameter of the body of the first sacral vertebra at its widest point (Figure 7). Because a posterior spur may occur, or some osseous hypoplasia may become evident at that area, establishing this point can be difficult. We follow the method shown by Wiltse[80] to overcome this as depicted in Figure 8.

Advantage

1. Does quantify percentage of slip.
2. Help in quantifying the improvement or worsening after surgical correction and at follow up.

Disadvantage

1. More inter and intra observer variability
2. Difficult to reproduce accurately in poor quality x-ray

NEWMAN**'s** [75]method divides dome and anterior surface of sacrum into ten equal parts. The division along the sacral dome starts from posteroinferior corner of S1 and division along the anterior surface of S1 start at the sacral promontory. Scoring is based on position of posterior inferior corner of L5 with respect to dome of S1 and the position of anteroinferior corner of L5 with anterior surface of S1. (Figure 9)The score by this system therefore includes two numbers. The first indicating the position of posteroinferior corner of L5 body and second the position of anteroinferior corner of this vertebra. e.g. A typical score therefore might be 2+0, the 2 indicating the amount of slip and the 0 indicating the extent of forward roll of L5 over S1 and the amount of downward displacement of the 5th lumbar vertebra with respect to the top of 1st sacral vertebrae.

Advantage

1. Measures forward slip.

2. Measures forward roll.

Disadvantage

1. More complicated than other 2 systems.
2. Difficult to interpret and reproduce.
3. Inter and intra observer variation is much more.
4. Difficult to find out the maximum anteroposterior width of S1 in high dysplastic variety.

SACRAL INCLINATION OR TILT

It measures the degree of vertical orientation of sacrum which is normally more than30^0 (Figure 10). The angle formed by line drawn on posterior aspect of first sacral vertebral body and a line drawn in vertical axis on standing lateral view. Normally when the patients stand, the sacrum is inclined forward. But tends to become more vertical ($< 30^0$) with increasing shear force at L5-S1.

ROUNDING OF FIRST SACRAL VERTEBRA

As the fifth lumbar vertebra glides forward, the top of the sacrum tends to become rounded (Figure 11). As the slipping and sagittal rotation increase, the rounding process progresses further posteriorly. We follow the method of quantifying in percentage the degree of rounding of the cranial border of the first sacral vertebra. Rounding of the proximal sacrum has been proposed as a risk factor for progression by some authors[81-84]while others regard it as a secondary phenomenon. [82 83 85-90]

SLIP ANGLE

This has been called “sagittal roll”, “Lumbosacral kyphosis”, and ‘‘slip angle’‘, and is the angular relationship between the body of the fifth lumbar and first sacral vertebrae (Figure 12). It is measured by a line along the posterior aspect of the body of the first sacral vertebra relative to a line drawn along the superior endplate of L5. So also we can use either anterior aspect of the body of the fifth lumbar vertebra or a line drawn to the inferior endplate of L5. Later 2 methods often leads to erroneous measurements due to growth inhibition of posteroinferior portion of L5 body (“false slip angle“).

Normally the slip angle at L4-L5 and L5-S1 is either zero or negative. The slip angle is most sensitive indicator of potential instability. It can be used to prognosticate progression of listhesis. Recently, not only L5-S1 but also L4-S1 is used in significant slip at L5-S1. This is due to marked compensatory and opposite angulation between L4 and L5 ,the spatial relationship between L4-S1 may approach to normal[80].

LUMBAR LORDOSIS

Normal Lordosis varies from 47^0 tangential radiologic assessment of lumbar lordosis **(**TRALL method) [91] and 52^0 in (COBBS method) after infancy[92]. It’s a compensatory phenomenon rather than a part of primary deformity. This describes the angular relationship between a line drawn across the top of the body of L1 and on top of L5. If the 2 lines do not intersect on film, perpendiculars are drawn to these lines to give lumbar lordosis (Figure13).

No significant differences are seen between standing and supine lumbar lordosis. Assessment of lumbar lordotic angle at preoperative and immediate postoperative and final follow up will indicate if the spine is mechanically realigned. A hyperlordotic spine indicates mechanically unbalanced spine and thereby increase lumbosacral shear force at L5-S1.

LUMBAR INDEX

This determines the amount of wedging of the listhetic vertebrae. This is obtained by dividing the height of the posterior border of L5 body by the height of the anterior border and multiplying by 100 (Figure 14).

LUMBOSACRAL ANGLE

This has been also called as “Ferguson’s angle”[93](Figure 15). In a mechanical balanced spine, the normal angle should be 40^0-44^0 [94]. In the postoperative or at follow up X-ray if the angle more than 44^0 it suggests a more vertical sacrum and increased shear force at L5-S1. It has been already proved by the study , that any dysplastic L5-S1 listhesis with vertical sacrum is likely to progress if untreated[95]. Realigning lumbosacral angle decreases the shear force at L5-S1 level and therefore measurement of immediate postoperative and follow up X-rays are important. It may indirectly tell us the mechanical alignment, malalignment; shear force at L5-S1 and possibility of progression of listhesis in future.

Radiographic measurements in spondylolisthesis are predictors of slip progression and aid in treatment decisions, but their usefulness depends greatly on their reliability. Slip angle, Meyerding's grading and sacral inclination had excellent intra and interobserver reliability and may be the most important parameters in evaluation on listhesis. [80]

NEURORADIOGRAPHIC STUDIES

In the evaluation of listhesis Neuroimaging have been extensively used to further qualify the effect of listhesis.

Discography use is grossly limited only to confirm the disc degeneration above or below the level of listhesis which will help in deciding the level of fusion. The main disadvantage this procedure being high rate of infection.

Radionuclide imaging Single-Photon-Emission Computed Tomography of a scintigram enables localization of signal to the posterior vertebral elements, specifically the pars interarticularis[96]. Increased signal intensity suggests osseous activity and healing potential, whereas absence of an increased signal suggests a non-union and diminished healing potential[97].

Computer Tomography scan defines the bony pathology and pedicle dimensions measured preoperatively for surgical reconstruction. Specifically useful in detecting Pars Interarticularis defect with fibrocartilagenous mass at the L5 level or healing of Pars Interarticularis defect after immobilization. It is extensively used to assess fusion in postoperative follow up evaluation.

Magnetic Resonance Imaging demonstrates neural anatomy and the source of neural impingement and allows disc signal comparison at other potentially symptomatic levels. Ulmer et. al reported on "wide canal sign" a reliable detector of Isthmic listhesis[98]. Sagittal canal ratio of 1.25 or greater indicates bilateral Pars Interarticularis defect in 97% cases. The potential advantages of MR imaging include the ability to accurately define

1. Intervertebral foramen and nerve root in foramen.
2. To identify possible conus abnormalities.
3. To assess the hydration status of discs.
4. As well as possible disc herniation above the slip.
5. To identify occult defects in pars interarticularis.

In our practice, MR imaging is modality of choice in preoperative assessment of adult patient with spondylolisthesis.

POSTERIOR LUMBAR INTERBODY FUSION

These patients underwent decompression, posterior instrumentation, reduction and Posterior Lumbar Interbody Fusion (PLIF) with 2 Harms' cage. PLIF with posterior instrumentation was first popularized by Cloward [68]. PLIF was based on a sound biomechanical rational because the main forces in lumbar spine pass through disc space, which primarily compresses at anterior strut graft , a load sharing structure and large fusion surface area.

Advantage of PLIF

1. Large surface area for bone grafting.

2. Structural grafts may restore disc height and segmental lordosis.
3. Direct nerve root decompression by excision of “rattler” and “bony hook”
4. Indirect nerve root decompression through intervertebral foramen enlargement.
5. Avoids second anterior incision and thereby less chance of retrograde ejaculation
6. No need for assistance from vascular or general surgeons.
7. Mild slips may be reduced by discectomy and grafting.

Disadvantage of PLIF

1. Epidural scarring.
2. Injury to dura by the screw.
3. Increase bleeding and surgical time.
4. Need expertise and longer learning curve.

For ventral column support and stability, interbody fusion with Titanium cage (**Harms’** cage) has been widely used by us since 1991.

Advantage of cage [99]

1. Restoration of anterior column.
2. Definitive support of the reduction.
3. Maintenance of Intervertebral disc height.
4. Marked reduction of the shear forces at the lumbosacral joint by pressing the

peaks of the cage into the end plate.

5. More rapid healing of the cancellous chips compared with cortico-cancellous bone blocks.
6. Prevent of collapse of the bone blocks.
7. Reduction of morbidity at the donor side by eliminating the use of bone blocks.

Complications of PLIF

1. Graft related
    a. Delayed union if corticocancellous block is used.
    b. Non union.
    c. Pseudoarthrosis.
    d. Graft absorption.
    e. Graft collapse.
2. Surgery related
    a. L5 or L4 root damage.
    b. Infection.
    c. More blood loss.
    d. Epidural fibrosis.

AIMS & OBJECTIVES

1. To study the clinical outcome of patients undergoing surgery for low grade dysplastic spondylolisthesis.

2. To study Radiological outcome at follow up of these patients.

3. To identify the various surgical and radiological features contributing to the functional and radiological outcome.

4. Complications of posterior lumbar interbody fusion with pedicle screws and titanium cages.

MATERIAL & METHODOLOGY

It is a retrospective case series, analyzing sixty one patients selected from the hospital records, operation theatre registry of the Spinal Disorders Surgery unit of the orthopaedic department at Christian Medical Collage, Vellore. The study period was 6 years starting from July 2001 till July 2007. Outcome data of 37 patients with more than 2 years follow up were collected and their results were analyzed. Informed consent in their vernacular language was obtained from patients explaining the pros and cons of the study, and their role. At no point in time was any financial assistance or assurance given.

The inclusion criteria were [76-78]:-

1. Failed conservative line of management with debilitating back and leg pain.
2. Neurogenic claudication pain with walking distance less than 500 meters.
3. Deteriorating neurological status.
4. Cauda equina syndrome.

The exclusion criteria were:-

1. High Grade spondylolisthesis –Grade III, IV, V.
2. Degenerative listhesis, traumatic, Iatrogenic and pathological listhesis.
3. Previously operated patients for spondylolisthesis.

The study group was comprised of patients with isthmic pars defect or elongated pars low dysplastic spondylolisthesis. They underwent neural decompression, posterior pedicle screw instrumentation, and Posterior Lumbar

Interbody Fusion with 2 Harms' cages and bone graft.

The preoperative parameters that were recorded include - patients' name, age, gender, contact address, type and grade of spondylolisthesis. Detailed history of preoperative non-operative line of management, co-morbid conditions and their treatment, additional risk factors like smoking, family history, menopausal history were analyzed.

Clinical symptoms of back pain and leg pain, duration of these symptoms in months, and pain severity scoring with the help of Visual Analog Scale. Pain was categorized into three patterns: patients with leg more than back pain, only leg pain or back pain. Importance was given for the maximum walking distance before they had to take rest.

Detailed neurological examination of motor and sensory deficits was recorded. We noted their gait pattern, deformities of spine, local tenderness, and palpable step. Bowel and bladder dysfunction was assessed.

Radiological assessment consisted of standard anteroposterior view in standing, 30^0 Ferguson view and lateral x-rays in neutral, flexion and extension were taken. X-rays were ordered preoperatively, immediate postoperative and at final follow-up. Preoperative MRI was done to evaluate the degree of degeneration and extent of compression of neural and thecal sac, canal dimensions and adjacent segment disc status. Various radiological parameters like grading of slip was based on Taillard's method, true slip angle, lumbar lordosis, lumbosacral angle, lumbar index, sacral rounding and sacral inclination. Spondylolisthesis was documented at L5–S1 and at L4–5 level in case of sacralized L5.

During the final follow up we documented the persistence or recurred clinical symptoms, so also their motor charting, sensory assessments, pain free walking distance were recorded. Postoperative complications and their sequelae were recorded. Small sliced limited cut CT scanogram in coronal, sagittal and transverse was obtained in patients in doubtful fusion at graft site or if translation more than 4 mm in flexion-extension views.

Functional assessment was done using modified Japanese Orthopedic Association [61 100] score (Table 4) totaling up to 20 points and Oswestry Low Back Pain Disability Questionnaire[101](Table 5) total score of 50. JOA scoring includes all components like Subjective, Objective, including bowel and bladder involvement with total scoring of 12, 8 points in each section. It was modified in order not to overlook cauda equina findings, particularly in patients with a slippage at L5-S1[61].

Oswestry questionnaire which has stood test of time was also used in assessing disability in our patients. It is more of subjective rather than objective questionnaire. With 5 questions each under 10 categories like Pain, difficulty in Personal Care, Lifting of weight, walking, sitting, standing, sleeping, sexual activity, traveling & social life. Each section had a scoring from 0-5.

All patients in this study had reported to us after failed non- operative treatment. The symptoms were severe enough to seek surgical line of management.

SURGICAL OUTCOME ASSESSMENT

A. RADIOLOGICAL ASSESSMENT

Various radiological indices which influence the final outcome after surgery were studied. Those are

1. Percentage of Sagittal translation
2. Slip Angle
3. Sacral Inclination
4. Lumbo-Sacral Angle
5. Lumbar Index
6. Lumbar lordosis

B. <u>FUSION MASS ASSESSMENT</u>

The difficulty of assessing solid fusion, in the presence of fixation, has to be acknowledged. [57 102] However, it is easier to assess the fusion mass as compared to poster lateral fusion.

Advantages are:-

1. It requires lateral film plain X-rays only.
2. No lamina or the pedicle interference with vision.
3. Signs of nonunion or pseudoarthrosis are easily visible.
4. Posterior implants especially pedicular screw without anterior cages does not interfere.

Signs of Solid Fusion

a. Derived from radiographic confirmation of continuous bony trabeculae traversing the grafted segments between upper and lower end plate.

b. Most reliable radiographic indication of fusion postoperatively as per McAFEE is the *Sentinel Sign* or the presence of bridging bone anterior, posterior, medial or lateral to the fusion cage . [103]

c. "Functional arthrodesis" translational motion typically < 4 mm on flexion and extension radiographs and bridging bone anterior or posterior in an apparently fused segment. [39 43 53 57 104-107].

d. Additional evidence of fusion

   i. Lack of implant loosening, breakage.[108]

   ii. Absence of lucency around screws. [108]

   iii. Progressive vertebral displacement or increasing deformity. [108]

Signs of "Indefinite Fusion"

a. Definite zone of lysis between the graft and vertebra above and below.

b. Graft resorption.

c. Graft breakage.

It takes nearly a minimum of 6 to 9 months for consolidation of fusion mass. However trabacular connectivity pattern may not occur even as late as 3years in the absence of pseudoarthrosis. [109]

Signs of Pseudoarthrosis

a. Visible gap.

b. More than 4 mm motion at spine segment on flexion extension X-rays.

c. Screw Breakage.

d. Lysis around the Screw.

C. *FUNCTIONAL ASSESSMENT*

Functional assessment is the most important surgical outcome evaluation. It provides the ultimate end result of surgery to the patients and surgeons.

The subjective parameters are:-

a. Pain relief – back pain and leg pain.
b. Improvement in walking distance.
c. Improvement in activities of daily living.
d. Effect on occupation.
e. Frequency of non steroidal anti inflammatory drug (NSAID) consumption.

In addition to these other parameters taken into consideration are sexual activity and sleep disturbance. Based on all these parameters few scoring system aids in assessing patients preoperatively and postoperatively are:-

1) Visual Analog Score. (Annexure)
2) The Oswestry Low Back Pain Disability Questionnaire[101]. (Annexure)
3) Modified Japanese Orthopedic Association [110 61] scoring. (Annexure)
4) Hirabayashi [111] improvement in JOA scoring.

$$\frac{\text{Postoperative JOA} - \text{Preoperative JOA}}{\text{20 (Full Score)} - \text{Preoperative JOA}} \times 100$$

5) Paajanen[112] MRI Classification of Disc Degeneration. (Annexure)

OPERATIVE PROCEDURE

PATIENT POSITIONING

Patients were positioned prone under general anesthesia on a Relton-Hall frame leaving the abdomen free of pressure. The low back including the posterior iliac crest were prepared and draped.

INCISION AND EXPOSURE

Mid-line longitudinal incision centered over the prominent spinous process and extending one level above and one level below. After dividing the deep fascia and supra spinous ligament the para spinous muscle was stripped sub periosteally bilaterally, beyond the facet joints up to the base of the transverse process exposing the pars interarticularis. An attempt was made to preserve the facet capsule of the cephalad articulation.

PLACEMENT OF PEDICLE SCREWS

The pedicles of the vertebrae to be instrumented were probed with the pedicle probe under C-arm control. After appropriate tapping poly axial pedicle screws were placed to engage approximately 80% of the vertebral body length.

DECOMPRESSION

The defect in the pars interarticularis was identified when present and a total lamino- arthrectomy (excision of the `rattler') was performed. The vertebrae were then distracted using a lamina distractor or using a rod attached to the pedicle screws.

The dura and descending and exiting nerve roots were dissected carefully and retracted towards the mid line to expose the intervening inter vertebral disc. The bony hook was identified in the proximity of the exiting nerve root and excised to prevent the nerve root from being stretched over it.

POSTERIOR LUMBAR INTERBODY FUSION

The affected intervening disc was excised after appropriate retraction of the dura and nerve root. The corresponding end plates were curetted and the disc material removed carefully and thoroughly. In most cases this was done from one side alone. In few, the procedure was repeated through both sides. This step frees the two vertebral bodies completely and permits some amount of self correction of the listhesis.

The intervening space is filled with morselized bone graft usually taken from the excised rattler. The bone graft is placed in the anterior third of the intervertebral disc space. Two appropriately cut Harms' cages filled with bone graft were also placed in the middle of the disc space. Pre cut rods were placed on the both sides in the saddle of the poly axial pedicle screws and compression applied to correct and compress the interbody graft and cages. The final implant and cage position was checked with an Image Intensifier C-arm. Decompression of the dura and all the nerve roots was confirmed. After appropriate haemostasis the wound was closed in layers with a suction drain.

POST OPERATIVE CARE

Wound inspection and drain removal done on second postoperative day. Patients were made to sit up and mobilized with lumbosacral belt from second day. Static spinal exercises were started after surgical pain was reduced. On 10th post operative day suture removal was done. The patients are advised to wear lumbo sacral belt for 3 months duration. Any wound healing problems were stringently treated with secondary washout and parenteral antibiotics based on the culture report. Patients were evaluated at 1st 3rd and 6th month after surgery in the first year of surgery and then onwards, yearly once with regard to presence of back pain, leg pain, improvement in walking distance, neurological examination, radiological parameters like slip angle, lumbar lordosis, sacral inclination, lumbo sacral angle, stage of fusion and postoperative Oswestry and JOA scoring during their follow up.

RESULTS & ANALYSIS

Our study is a retrospective analysis of patients with low dysplastic spondylolisthesis examined and treated in the Spinal Disorders Surgery unit of Orthopedics department, Christian Medical College, Vellore, between July 2001 and July 2007. During this 6 year period a total of 61 patients underwent surgery. Of these, 24 patients were lost to follow up, which includes 2 patients who expired and seven patients who had registered with incorrect residential addresses. Of the remaining 37 patients, 29 patients were followed up personally and 8 patients based on the hospital records of at least two years following the index surgery were analyzed. (Figure 16)

DURATION OF FOLLOW UP

Mean duration of follow up after the index operation was 59.79 months (range 29–102 months). Two patients expired, one a natural death and the other following chronic renal failure. No deaths were related to the index surgery for spondylolisthesis.

GENDER DISTRIBUTION

This study group of 37 comprised of 11 males and 26 females. In our study the Male: Female ratio was 1: 2.4.

AGE OF PATIENT AT SURGERY

Our patients' age ranged between 26 years to 67 years with mean of 45.6 ± 9.4 years age. Seventeen patients were in their 5th decade; nine patients were in their 4th decade and two patients in their 7th decade.

COMORBID CONDITIONS

In our study group, 16 (43.2%) patients had no associated co-morbid conditions (Figure 17). 5 patients had Type 2 Diabetes Mellitus, and their sugar levels were well controlled before surgery. 7 were post-menopausal women and 2 were in their pre-menopausal status. These women received calcium supplements following surgery till their final follow up. There were 4 hypothyroid patients and 3 hypertensive patients on regular medication. Our group had only 2 chronic smokers, both were male. The other associated co-morbid conditions were Sjogren's syndrome with renal failure in one patient and morbid obesity in another. 3 patients had more than one co-morbid condition.

LEVEL OF LISTHESIS

Spondylolisthesis was documented at the level of L5-S1 in 19 patients (51%) and at L4-L5 in 18 patients (49 %). All the patients in L4-L5 group had sacralized L5, thereby suggesting that it was the last mobile spinal segment which was always affected.

TYPE OF LISTHESIS

In this group, thirty two patients had break in the pars and the remaining five belonged to elongated pars type spondylolisthesis, either grade 1 or grade 2 with symptoms severe enough to warrant surgery.

DEGREE OF LISTHESIS

Grading of spondylolisthesis was based on the Taillard's method [16]. This study included adult patients, specifically with a "low-grade" listhesis. Before surgery, 6 patients (16.2%) had grade I and 31 patients (83.8%) had grade II listhesis. In the immediate post-operative and final follow up period, there was an increase in the number of patients among grade I listhesis from 6 to 27 (73.0%) patients as 21 patients from grade 2 were reduced to grade I. (Figure 18) 10 patients (27.0%) had persisting grade II listhesis.

CLINICAL EXAMINATION SPONDYLOLISTHESIS PATIENTS

Thirty seven patients in our study had low back pain for average duration of 81 months (range from 3 to 336 months) with most patients suffering from back pain for 120 months (10 years). Visual Analog Scoring of the preoperative low back pain was 6.15±1.9 (Figure 19). At final follow up 33 out of 37 patients (89.2%) had shown improvement in low back pain with an average improvement of 49.7%. 5, 10 and 8 patients (total of 23 patients -62.1%) had back pain VAS of 0,1,2 respectively.

Commonest presentation was radiculopathy with leg pain and claudication. Mean duration of leg pain was 34.5 months (range 3-132 months). Leg pain was of shorter duration as it developed later than low back pain. Average VAS for leg pain was 5.3 ± 2.6. Two patients complained of rest pain with back pain duration of 120 and 138 months. At final follow up, 35 out of 37 patients (94.6%) had improvement in leg pain VAS with an average improvement of 49.5%. 8, 11 and 11 patients (total of 30 patients – 81.1%) had VAS of 0, 1 and 2 respectively. The improvement in leg pain VAS score was not related to the duration (p=0.992), the age (p=0.998) or the gender (p=0.294) of patient.

33 out of 37 patients (89.2%) showed improvement in both back and leg pain VAS. One patient who showed deterioration underwent late reoperation for adjacent level degeneration.

CLAUDICATION PAIN IN THE LOWER LIMBS

Patient disability was evaluated by noting their maximum walking distance due to claudicating pain before they had to rest. The average preoperative walking distance was 332 meters (range 50-1000 meters). 59.5% (22 patients) were able to walk 500 meters. 34 patients (92%) had relief of claudicating pain by sitting, while the remaining three patients got relief only by lying down and so were home bound with walking distance less than 250 meters.

At final follow up improvement of the clinical features was confirmed with improvement in their walking distance from average of 332 meters to 1989 meters. 18 patients (48.6%) were able to cover comfortably the distance of 1.5 kilometers and 11 patients (29.7%) could walk more than 2 kilometers. One patient who was able to walk only 100 meters at the time of final follow up had to undergo revision surgery for adjacent level degeneration.

OTHER CLINICAL FINDINGS

On analyzing the gait 31 patients had normal gait pattern. 7 patients (19%) had stiff back gait. 20 patients (54.1%) had exaggerated lumbar lordosis. On examination 17 patients (46%) had a spinal list preoperatively, with list to the right side in 7 patients (18.9%) and list to the left side in 10 patients (27.0%). 73% (27 patients) had clinically palpable step. Straight leg raising test was negative in 35 (94.6%) of our patients so the remaining 2 patients had positive SLR of 60^0 and 40^0.

At final follow up, only 1 patient had clinically persistent exaggerated lumbar lordosis and 1 patient had persistent list to the left side. 2 patients who had positive straight leg raising test improved and were negative at final follow-up.

NEUROLOGICAL DEFICITS

22 patients (59.5%) had no neurological deficits (motor and sensory) in the preoperative, immediate postoperative or at final follow up. Clinical examination

revealed neurological deficits due to nerve root entrapment which correlated with radiographic and MRI imaging in 15 patients (40.5%) (Table 6). Among them 7 patients (46.6%) had hypoesthesia of 10%-50%, isolated motor weakness in 2 (13.4%) and both sensory and motor deficit in 6 patients (40%).

The neurological dysfunction improved in motor and sensory status after decompression and stabilization. 4 out of 8 patients (50%) had motor recovery postoperatively. 2 patients with motor power of grade 3/5 and grade 4/5 recovered fully. Two patients showed improvement, one from grade 2/5 to 3/5 and another from grade 3/5 to 4/5. Remaining 3 patients with grade 4/5 motor power and 1 patient with grade 3/5 motor power did not show improvement. Sensory deficit persisted in 5 out of 13 patients, of which 3 patients had 10% hypoesthesia and 2 patients had 50% hypoesthesia.

Out of 37 patients in our study, preoperatively three patients (8%) and postoperatively one patient had bladder involvement. Three patients recovered fully within a month. Only one patient at the final follow-up had persistent bladder dysfunction and she was advised intermittent clean catherization. All these patients with bladder involvement had a preoperative walking distance less than 250 meters with leg pain VAS around 8 to 10.

RADIOLOGICAL OUTCOME AND ANALYSIS

Success of surgery in spondylolisthesis is based on correction of the altered alignment of spine in sagittal plane. This is radiologically assessed by measuring slip angle and lumbar lordosis angle. In our study, there was significant improvement in lumbar lordosis angle from its preoperative mean of 36.46^0 to final follow up mean of 30.7^0 (P=0.028)

There was a significant improvement in the degree of spondylolisthesis (Table 7). While preoperatively the average percentage of slip being 34.8±1 (ranged 10.75%- 50.70%).At final follow up the percentage of slip reduced to an average of 22% (p=0.000). This value was statistically significant.

The mean preoperative slip angle was 19.8^0. This was reduced to a mean of 17.9^0 in final follow up x-ray which was not statistically significant. Lumbosacral angle improved from mean of 40.62^0 to 35.39^0 in the final follow up radiograph; however this value was not statistically significant.

NON-OPERATIVE MANAGEMENT

Most of the patients in the study group had undergone conservative line of management before they were seen by us with severe symptoms that warranted surgery. 16 patients were using a lumbosacral belt for a mean duration of 8.5 months (range - 1 to 27 months). 13 patients have had treatment with pelvic traction for an average of 7.8 months (range 1 week to 48 months). 14 patients had undergone physiotherapy which included short wave diathermy for a mean duration of 27.3 months (range 3-84 months). 1 patient had received Epidural Steroid Injection.

OPERATIVE MANAGEMENT

BLOOD LOSS

In the index surgical procedure there was an average blood loss of 415 ml. There was no statistically significant association blood loss during surgery with age, gender, type of listhesis, degree of listhesis or patient developing pseudoarthrosis**.** But there was statistically significant association with the duration of surgery (Table 8).

DURATION OF SURGERY

The mean surgical duration in our study was 3.63±0.18 hours. There was no statistically significant association between the duration for surgery and degree of listhesis, type of listhesis or the patients developing pseudoarthrosis. (Table 9)

COMPLICATIONS OF SURGERY (Figure 20)

Nine patients had complications (25.7%). They were

1. Intra - operative - Dural tears, pedicle breakage, vascular injury.
2. Early postoperative - Superficial or deep wound infection, wound gaping, cauda equina syndrome
3. Late postoperative - reoperation either due to pedicle screw loosening or breakage, Pseudoarthrosis, recurrence of listhesis, death.

1. INTRA - OPERATIVE

ACCIDENTAL DURAL LEAK

There were two patients with intraoperative dural tears which were primarily repaired with 6-0 vicryl and packed with fat pad. In the post- operative period there was no CSF leak or symptoms associated with it.

There were no cases of pedicle breakage or vascular injury.

2. EARLY POSTOPERATIVE

BOWEL & BLADDER DYSFUNCTION

One patient had bowel and bladder involvement postoperatively which recovered within a month. Of the other three patients with preoperative bowel and bladder involvement, two patients recovered and other one patient persisted to have bladder dysfunction and managed by intermittent clean catherization.

SURGICAL WOUND INFECTION

In our study we had complication of immediate postoperative wound infection. There were no cases of superficial wound infection. Four patients (10.8%) developed deep wound infection. All these patients required surgical debridement and a course of parenteral antibiotics followed by oral antibiotics for total of 6 weeks period. Of this one patient had documented Methicillin resistant Staphylococcus aureus (MRSA) and parenteral Vancomycin was given for 10 days followed by oral Lincomycin and Rifampicin. The remaining 3 patients had no growth on culture report. They were given empirical antibiotic cover. They were discharged only after wound healing. The average hospital stay for these 4 patients was 20.75 days. All these patients with deep wound infection were non-diabetic individuals.

At the final follow up these four patients had neither implant loosening due to infection nor persistent sinus discharge. These patients recovered from wound infection so well that their mean back pain VAS was 1.25 at final follow up. On analyzing these patients final clinical outcome according to JOA was excellent to good, with Oswestry were mild to moderate disability (Table 10). This was comparable to the rest of the group in our study.

3. LATE POSTOPERATIVE

LATE REOPERATION

2 patients who underwent spine surgery at the later date were not included as they don't fit into the criteria of reoperation. One patient had elective hardware removal after fusion as the patient requested for same at the end of 64 months. Another patient developed degeneration and recurrence of symptom, instability and neurological deficit at an adjacent level. He required reoperation and extension of fusion and fixation after 37 months postoperatively.

ADJACENT LEVEL DISC DEGENERATION (Figure 21)

48.6 % (18 patients) had normal adjacent level discs. In the preoperative period 12 patients (13.5%) in our study had adjacent level involvement based on MRI Preoperative MRI was not traceable in 7 patients. Among 12 patients 41.7% of them showed grade 2 degenerative changes on MRI. The MRI grading from 1 to 4 was based on a classification proposed and modified by Paajanen et.al[112]. At the time of final follow-up repeat MRI was not available to comment on the progress of degeneration in these 12 patients. The functional outcome based on Oswestry Low Back Pain Disability Questionnaire and JOA was statistically significant with adjacent disc degeneration (0.028 and 0.036). The association with the age, gender or the type of listhesis had no statistical significance on the adjacent level disc degeneration. One patient with grade 4 adjacent level degenerative disc change in preoperative MRI underwent cephalad extension of the PLIF at 37 month postoperatively due to recurrence of symptoms with claudicating pain and walking distance of 100 meters. There was good fusion at the operated level. Another patient with grade 4 adjacent level degenerative disc change had poor preoperative JOA and improved at final follow up.

INTERBODY GRAFT FUSION

In our study 94.6% (35 patients) had bony union at the grafted inter-body fusion site (Table 11). 20 patients had good bony fusion with definitive bony trabaculae connecting across the end plates both within and around the cages. However 7 of these 35 patients had positive sentinel sign with no definitive trabaculae across the vertebrae or displacement on dynamic flexion-extension view. In 8 patients with absence of sentinel sign and bony trabaculae, interbody fusion was confirmed with less than 4mm displacement on flexion-extension views with no signs of lucency around the pedicle screw or breakage of implant. 5 of these 8 patients were further confirmed by CT on sagittal and coronal views which showed union. Definite nonunion or ‘Pseudoarthrosis was seen in two patients. One patient had screw breakage and another patient had nonunion confirmed by CT scanogram.

However graft fusion had strong statistical significance with the age of the patient, younger the age higher was the fusion if we consider bony trabaculae and sentinel sign positive patients only, as they represent definitive radiological bony union (P=0.005) (Table 12). Interbody fusion showed no significant association with the gender, type of listhesis, level of spondylolisthesis, adjcent level involvement, low back pain or leg pain VAS scores.

FUNCTIONAL OUTCOME

In our study, assessment of functional improvement before and after surgery was evaluated with two scoring systems. First is the Japanese Association of Orthopedic score [110] with Hirabayashi improvement scoring[111] methodology. Second one was Oswestry Low Back Pain Disability Questionnaire[101]. Both these scoring system provided composite functional assessments objectively and subjectively, including the ability to do activities of daily living relevant in the Indian scenario.

At the final follow up mean modified JOA with Hirabayashi improvement score for 33 patients (89.2%) were in excellent to good category with mean score of 70.51% representing "*good*" improvement (Table 13). The Oswestry Low Back Pain Disability Questionnaire score for 31 patients (83.8%) were in mild and moderate disability category with mean score of 18.7% falling into "*minimal disability*" (Table 14). Both scoring had a statistically significant improvement in this final follow-up.

The severe disability group had 6 patients (Figure 22). One patient had co-morbid condition of Sjogren's syndrome with renal failure, 2 others were hypertensive and hypothyroid. These 6 patients average walking distance preoperatively was 558 meters with mean back and leg pain VAS of 6. At final follow up back and leg mean VAS of 4 and 3.5.One patient in this group had developed pseudoarthrosis. In this category 2 patients had grade 3 and one had grade 4 adjacent level disc degeneration on MRI. One of these patients had PLIF at the adjacent level for recurrence of symptoms.

Two factors like back and leg pain VAS had statistically significant association (p=0.035 & p=0.004) with severe disability category in the Oswestry questionnaire. Most of the severe disability group patients had consistently scored higher disability points in few sections of question. E.g., they had disability to sit or stand for more than half an hour or lifting weight from floor or unable to travel more than an hour or in need NSAID for pain relief which carried 3 points or above. This severe disability is compounded by more of subjective rather than objective factor.

These functional scores were compared with the various factors in this study.

On analyzing the functional scoring, we found that preoperative displacement of the listhesis by Taillard's' method had high significance on functional improvement, but slip angle had no influence on the outcome (Table 15).

DISCUSSION

Our study is designed to assess the clinical and radiologic outcome of low grade dysplastic spondylolisthesis for the treatment of chronic back and leg pain, with progressive neurological deficit in spondylolisthesis. Unlike other spinal disorders, management decisions in adults with low-grade spondylolisthesis need to take into account the natural history of the disease, the severity, duration of symptoms, and patients' co-morbidities.[7] Studies on the long-term follow-up of low grade spondylolisthesis by Frederickson et al[73] and Beutler et al [113] have shown that the natural history of this condition is typically to be a benign one. While progressive displacement may occur as the result of disc degeneration at the listhetic level, the magnitude of such progression is small.

At present there is no consensus regarding the optimal surgical treatment or an acceptable non-operative regimen. The decision to recommend surgical treatment to an adult patient with low-grade spondylolisthesis must be carefully individualized.[7] The prospective randomized trial reported by Rosenberg WS[114], Madan & Boeree [115] indicated that intervertebral fusion can provide favorable clinical outcomes as compared to prolonged supervised exercise program.

Though this study is a retrospective analysis, we endeavored to evaluate the value of decompression and posterior lumbar interbody fusion (PLIF) with Harms' cages in Grade 1 and 2 spondylolisthesis as the method of treatment. Presently treatment of choice for symptomatic spinal stenosis with intermittent neurogenic claudication is a complete decompression of the neural elements.[69] Decompression of the spondylolytic spondylolisthesis results in gross instability from loss of entire posterior stabilizing structures in the face of incompetent anterior support and necessitates a fusion[116 117]. Pedicle screws provide rigid fixation and aids in fusion following decompression in spondylolisthesis[118]. It also facilitates restoring the normal biomechanics. PLIF method offers increased surface area[119] for fusion, reduction of the listhesis, and provides an anterior support. Posterior pedicle screws and anterior cage construct enhances fusion by tension band principle. Most of the low grade listhesis reduce almost completely at the time of surgery and rarely need manipulation; reduction may be achieved by many methods, including instrumental reduction, leverage.[120 121] We prefer the pedicle screw-rod system as it is less bulky and easier to apply compression.

Circumferential fusion using anterior interbody fusion also has shown satisfactory outcome that can reduce and stabilize involved segments[122], however it cannot directly address the problem of radicular pain, which requires a posterior approach resulting in more tissue trauma and potential for complications because of two incisions and increased operative trauma[123]. On the other hand, PLIF may be done posteriorly through a single incision, and when combined with PLF, it reconstructs anterior and posterior columns to give a circumferential fusion.[124] PLIF, besides offering a broad bone base anteriorly, enhances the fusion of the graft by elimination of the disc space motion and restoration of the disc height, thus reducing the bending movement of the graft and narrowing the gaps between the fusion bases.

The use of PLIF with spacers perhaps improves stability and graft sinkage that can occur with bone grafts alone.

Posterior lumbar interbody fusion often is considered a difficult procedure and had been accused of causing many complications including graft protrusion, neural injury, excessive bleeding, adjacent-segment morbidity and increased operation time.[124 125] We believe these complications may by simplified by using two cages with cancellous bone graft to support the endplates. Cage with bone graft tightly abuts on the endplates, eliminating the danger of graft dislodging and protrusion.[69]

PREVALANCE OF LISTHESIS

Several epidemiological studies have revealed that the incidence of symptomatic listhesis in Caucasian populations varies from 4 to 6% [20 126 127]but rises as high as 26% in secluded Eskimo populations. It varies from 19 to 69% among first-degree relatives of the affected patients [128]. Beutler et al[113] described the natural history of isthmic spondylolisthesis, and stated that in their study population, the incidence of disability and low back pain in spondylolisthesis was similar to that in the general population. [113] Incidences in our study group were 16.2% in Grade I listhesis, 83.8% in grade II listhesis. Osterman et al[129] noted that the lower grades of spondylolisthesis are far more common at the time of presentation: grade I 79%; grade II 20%; grade III 1%.

Many clinical and radiographic factors have been analyzed as predictors of slip progression. These include female gender, prepubescence, increased slip angle, trapezoidal L5, domed and vertical sacrum[130] bifid sacrum, dysplastic facet, break in pars interarticularis, disc degeneration and sagittal rotation.[131] It is difficult to determine if these parameters are primary or secondary adaptive changes. Ikata et al proposed that L5 wedging and S1 doming are actually adaptive changes. [86]Low dysplastic types have a rectangular L5 body, parallel adjacent lumbosacral endplates, preservation of a flat first sacral superior endplate, and no sacral verticalization [132].In a dysplastic lumbosacral region progression of slip beyond 25% is not possible without a concomitant break in the pars interarticularis[62].

DURATION OF SYMPTOMS

In our study 24 (39%) patients were lost to follow up after the index surgery which includes 2 patients who expired unrelated to our surgery. 2 categories of patients, first group comprising of patients examined at their final follow up in outpatient department, and second group were patients with more than 2 years of follow up data from hospital records following surgery. Average follow-up period was 58.86 months (~6 years) ranging from 29 to 102 months. Two patients expired, one a natural death and the second patients had chronic renal failure not related to spondylolisthesis.

During the follow-up period most of the patients did report mild worsening of back pain symptom after their drastic improvement in initial postoperative period. On analysis, duration of follow up showed no significant bearing on the follow up end results. Whereas Fritzell et al [133] reported a deterioration in results of lumbar fusion at the end of 2-year. They failed to give an explanation for the functional scoring and VAS deterioration in their study. But a degeneration of the adjacent facet joints and disc or an overloading of the sacroiliac joint might be responsible for this observation. [134]

PATIENT'S AGE AT SURGERY

Patients with the low dysplastic spondylolisthesis usually present as young adults. The slippage is characterized by translation without the angulatory or kyphotic component. Virta et al.[135] in their review of 1,100 individuals in Finland were ranging in age from 45 to 64 years. Our study group has similar outcome with age at first operation ranged between minimum age of 26 year to maximum of 67 years with mean of 45.59 ±9. As we see the age was above the adolescent, they might have developed the listhesis at younger age with symptoms developing at the later age. This fact being seen in other studies were the average age falls around the same range of 37 years, 53 years age[61 122 134 136]Boden et al[137] and Benoits[138] stated that disc degeneration is strictly correlated with age. In their opinion, significantly better results as well as the less rapid deterioration with dysplastic spondylolisthesis is highly correlated to the age of the patients.

The aforementioned studies suggest that in younger patients, there is less degeneration of the adjacent disc as well as facet joints. As stated by Benoits, [138] pain and disability are the clinical symptoms of the aging spine, although many factors of the aging spine remain unknown[138]. This would explain the better result as well as the less rapid deterioration because the younger patients will have significantly less degeneration of the adjacent joints and discs.

GENDER DISTRIBUTION

In our study of 37 patients, 11 males and 26 were females. Ratio of females was twice that of male. Virta et al. [135] identified a 2:1 ratio of occurrence in girls than boys. This gender ratio is maintained in other studies too. [122] [134] [139] One study reported ratio was as high as 4 times. [61]It is more common in females due to their hormonal influence on the ligament laxity, obese and strenuous working pattern in forward bending posture. Other studies also show no significant differences in pain outcome based on gender. [140-142]

CIGARETTE SMOKING

Cigarette smoking also represented a highly significant risk of failure for both return to premorbid activity and pain relief.[122] Ours study group had two male smokers, of which 1 patient had good pain relief and good functional scoring.

We found that both smokers had a 100% fusion rate , though numerous fusion series reveal a higher pseudoarthrosis and poor outcome rate in smokers.[39] [49] [143] [144] [53] [54] [57] [107] Moreover, DAFTARI and coworkers[145] reported experimental evidence that nicotine was associated with delayed vascularization, smaller areas of revascularization, and larger areas of necrosis in autologous cancellous grafts. This effect was not dose related or absolute. The authors postulated that smoking delayed early graft revascularization, leading to impaired osteogenesis and reduced cell counts. It is thus possible that smoking results in a hypocellular fusion mass, which could adversely impact clinical outcome.

Ransom and colleagues,[53] who reported that although pseudoarthrosis was not statistically correlated with smoking in patients treated with pedicle screws, smokers were still more likely to be clinical failures. We recommend that patients discontinue smoking once they are planned for surgery.

LEVEL OF SPONDYLOLISTHESIS

Dysplastic spondylolisthesis has been documented at the L5-S1 level. Either these patients had rounding of upper sacral end plate or dysplastic facet. Few of our patients presented to us with sacralized L5 with the last mobile spinal segment being L4-5 level. We had 51% with L5-S1 level involved. However 49% of patients had sacralized L5 with L4-L5 level involvement. We observe that L4-5 or L5-S1 level of listhesis remains irrelevant to the functional outcome. However no comment can be made about prevalence of L5 sacralization in general population. Conversely, we did not have any patients with lumbarized S1.

DEGREE OF LISTHESIS

In terms of describing the severity of listhesis, we used the Taillard's method based on the percentage of displacement. Though Meyerding scale is the most popular one, but has high inter and intra observer variability. The average listhesis in our study was 34.8 ±0.1%. It is higher than that described by Ishihara et.al.,[146] average of 26%. The degree of listhesis had statistically significant association at the final functional outcome.

LISTHESIS REDUCTION

Traditionally, in situ fusion has been the most widely used method for the surgical treatment of low grade spondylolisthesis.[78] Role of reduction in the treatment is still debated.[99 147] Some investigators are of the opinion that in low-grade spondylolisthesis, an instrumental reduction of the slip is unnecessary. [139] Nachemson and Wiltse[74] expressed the views of most contemporary surgeons when they wrote "*there can be little doubt that reduction is never indicated when the listhesis is less than 25% and hardly ever when it is less than 50%*". Those who advocate the surgical reduction of spondylolisthesis cite several reasons for doing so. Specifically, they contend that such a procedure will result in

1. Normalization of biomechanical function in the lumbosacral Junction.
2. A spine that is less difficult to stabilize by virtue of its reduction.
3. Reduction or elimination of neurologic complications.
4. Elimination of pain.
5. An increase in mobility.
6. Improvement in the appearance of the back.
7. Relaxes cauda equina. [148]
8. Enhanced fusion rates.

Disadvantage

1. Reduction is associated with a higher risk of injuring the L5 nerve root 10% – 20% of patients [121]
2. Harmlessness of the lumbosacral fusion in situ. [121]
3. Continue to slip forward after fusion. [121]
4. Persisting discomfort.[148]
5. Deformity of exaggerated lumbar lordosis is not reduced. [148]

In our study though no attempt was made to reduce the listhesis, there was reduction in degree of listhesis in the postoperative x-rays. On comparing the immediate post-operative and final follow up x-ray, 21 patients (56.8%) among grade 2 listhesis were reduced to grade I listhesis attributed to positioning. So the number of patients belonging to grade I listhesis increased from 6 to 27 patients.10 patients (27.0%) had persisting grade II listhesis due to insitu fusion. Grade I slip included patients with near full reduction. Of this seven patients at final follow up had listhesis of less than 10mm which was insignificant.

Although 56.8% of patients had achieved slip reduction from grade 2, this had no significant improvement in Oswestry disability grading[101] or JOA scoring[111].

VISUAL ANALOG SCORING (VAS) FOR PAIN

In our study, we placed great importance to clinical improvement in neurological deficit, leg pain and increase in walking distance. In our patients there was dramatic improvement in low back pain VAS from average of 7 to 2 which was statistically significant (p=0.00). On analyzing Oswestry score, six patients in severe disability group had persisting higher average back pain VAS of 3.5 at final follow up.

The next priority was given to radiculopathy or leg pain with claudication. All these patients developed leg pain later than low back pain. We had dramatic result with complete relief of claudicating pain on comparing preoperative VAS of 5.3 and final follow up VAS of 1.5 (p=0.00).

WALKING DISTANCE OF PATIENT

Maximum walking distance was used to assess physical disability indicating neural compression. As walking distance was quantifiable it could be used as an indicator for surgery. This important parameter has been used in both the functional scoring system. We had remarkable improvement in there postoperative walking distance to an average of 1989 meters. 29 patients (78.4%) were able to walk comfortably more than 1.5 kilometers at the time of final follow up. One patient at final follow up was able to walk only 100 meters, underwent revision surgery for adjacent level involvement.

NEUROLOGICAL DEFICITS

78.4% patients had no preoperative or postoperative motor deficits. Examination revealed reproducible neurological deficits either due to nerve root entrapment in the bony hook or disc herniation or spondylolytic gap that correlated with radiographic pathology. Neurological dysfunction too showed its improvement in motor and sensory status. 4 out of 8 patients (50%) had motor improvement. Two patients recovered fully and the other two patients showed improvement by 1 grade at final follow up. Sensory deficiency persisted in 5 out of 13 patients, with 10% reduction in sensory touch in 3 and 75% loss in 2 patients.3 patients (8%) had preoperative bladder involvement of which 1 persisted with bladder dysfunction and is maintained on intermittent clean catherization. One patient who developed bladder dysfunction postoperatively, recovered within a month.

RADIOLOGICAL ANALYSIS

Sagittal plane stability is disturbed in spondylolisthesis. Success of the surgery is based on correcting this component which can be assessed by measuring slip angle and lumbar lordosis. At final follow up the reduction in listhesis and lumbar lordosis was statistically significant (P=0.005), whereas lumbosacral angle, slip angle and Lumbar index were not statistically significant.

OPERATIVE MANAGEMENT

BLOOD LOSS

Blood loss is an inevitable drawback of this surgery. The average amount of blood loss in the index surgery was 415 ml that is comparable to average of 934 ml SCHNEE[122] or others like WOOD [149-151]JOHNSON [147]LORENZ [148]. We tried to pin down the factor which can be modified to reduce the loss. When we evaluated association of blood loss with factors like age of patient **(**P=0.978), gender of patient (P=0.204), type of listhesis (P=0.545), degree of listhesis (P=0.164) or patients who later developed pseudoarthrosis (P=0.806) were not statistically significant. SCHNEE, et al., [122] reported increased blood loss associated with the use of instrumentation, male gender, younger age, and operation on multiple levels. One factor statistically significant and modified blood loss in our study were patients with longer surgery duration (P=0.00). The use of a blood product recycling unit has become standard for lumbar fusions and is effective when blood loss exceeds 700 ml.[149] However none of our patients had that huge blood loss.

DURATION OF SURGERY

The duration of lumbar fusion surgery had no significant association with age of the patients, degree of listhesis, level of involvement or patients developing pseudoarthrosis. But it had direct bearing on the amount of blood loss during each surgery.

COMPLICATIONS

In our view, the few general complications observed in this series may or may not be related to the surgical procedure itself. Nevertheless, some patients had persistent problems. Our reoperation rate was nil comparable to 5.8% [122]to 17% reported in the cohort study[56]

ACCIDENTAL DURAL TEAR

Dural tears are a known potential intraoperative complication of spine surgery. Most of the studies in the literature are based on experience with relatively small numbers of patients. [152149153-155] Its reported incidence has varied from 1.8% to as high as 17.4%, with a wide variability of patient characteristics and surgical procedures.[154 156]

During surgery two patients (5.4%) with intraoperative dural tears were primarily sutured with 6-0 vicryl and fat pad was placed. In the postoperative period there was no CSF leak or symptoms associated to dural tear. MUSTAFA[157] evaluated dural leak in large series of patients and the overall rate in their study was 10.6%.MADAN [115]et.al. had no dural tears in the PLIF group. DiPAOLA[158] reported 5.4% and CHEN[159] study had 5.8% dural tear .

WOUND INFECTION

Our wound infection rate was 10.8% (4 patients) and all of them were non diabetic. None of them had superficial wound infection. All these 4 patients had deep wound infection needing immediate debridement and washout. Culture report on washout showed one patient with MRSA and remaining 3 patients with no growth. They were treated with parenteral antibiotic followed by oral for 6 weeks. Patient with MRSA wound infection was managed with parenteral Vancomycin followed by oral Lincomycin and Rifampicin. They were discharged only on wound healing. Their average hospital stay was 21 days, comparable more by 7 days than the patients with no wound problems.

However in spite of wound infections, the patients' average Oswestry low back pain disability was 29% and average modified JOA improvement scoring was 72% comparable to the rest of the group, suggesting deep wound infection did not bear any adverse functional outcome. Our infection rate was slightly on higher side as compared to WEGNER's study with one deep infection and one superficial wound overall 2.3%[136]. Similarly MADAN[115] had 4.3% with 2 deep infection, SUK had 1.3% [69] and LAUBER had 2.5% deep infection [134].BENLI reported two cases (4%) who had deep infections causing a delay in the wound. [61]None of these 4 patients had implant loosening or persistent discharging sinus at final follow up. We believe that if these wound infection are identified promptly and act swiftly they hardly have any long lasting consequences.

ADJACENT LEVEL DISC DEGENERATION

Adjacent segment degeneration is an enigma to the treating surgeons.

SCHLENZKA [160]et al reported a higher incidence of disc degeneration of the adjacent disc in adolescents with spondylolisthesis of L5-S1 compared to normal population. MIHARA et al[30] showed in-vitro an increased mobility of the adjacent joint following a defect of the pars interarticularis, which suggests that the patients with non-degenerative disease have degenerative changes already. Lumbar fusions introduce an increased stress on the adjacent level and longer the fusion, greater is the stress.[108 161]However, reports vary in the incidence and time interval before this stress manifests itself as a radiographic or clinically significant disease.[162] One series reported the incidence of adjacent segment degeneration as high as 35%[163]. It is uncertain if the adjacent segment degeneration reflect the natural history of lumbar disc disease or it is primarily due to the influence of a one or two level subjacent fusion. While both are probably factor, the goal should be to leave as many lumbar levels unfused, consistent with the goals of surgery.[108]

12 patients (32.4%) in our study had adjacent level involvement based on preoperative MRI. Most patients (42%) in our study were grade 2 as per PAAJANEN[112] classification. One patient (2.7%) underwent operation for disc and facet degeneration of an adjacent level involvement, presumably resulting from new stresses on vertebral motion created by the fusion. Involvement of an adjacent segment required operation in 2.4% of patients in 3 different cohort studies by WHITECLOUD[42] YUAN [55] ZDEBLICK.[43 56 57]

In our study adjacent level involvement had strong correlation with poor Oswestry or JOA functional scoring. The age, gender or the type of listhesis had no significant association with the adjacent level disc degeneration.

INTERBODY FUSION

Fusion techniques include posterolateral fusion, interbody fusion and circumferential fusion. The reported fusion rates for these techniques differ between 60% and 100%.[7 146 164-170] We preferred interbody fusion compared to others due to its advantages as explained in our earlier discussion.

Several studies of interbody fusion in spondylolisthesis and other pathologies using pedicle screws show a radiographic fusion rate from 90% to 100%.[69 115 171-173] The radiologic fusion rate of 94.6% in our study is comparable with the fusion rates of techniques using pedicle screws reported in literature. Because the radiograph was used as the golden standard for follow-up examination, only the radiologic fusion rate can be stated. Because of the limitations in sensitivity and specificity, this result might differ from reality.

The establishment of fusion was strictly derived from radiographic confirmation of continuous bone traversing the grafted segments, which showed no evidence of motion on flexion–extension radiographs.[174 175] In our study group, 20 patients had bony trabaculae traversing across the end plates. MCAFEE believed that most reliable radiographic indication of fusion postoperatively is the *Sentinel Sign*, or the presence of bridging bone anterior to the fusion cage. [103] This remains true even for the bridging bone on the posterior or the lateral aspect of the cages. These features are similar to the late maturation phases of callus formation no definitive trabaculae.[103] We had 7 patients with positive sentinel sign with inconclusive bone trabaculae within the cage.

The other method to confirm interbody graft fusion, referred as "functional arthrodesis” where translational motion is typically less than 4 mm on flexion and extension radiographs in an apparently fused segment. [36 104 105 43 53 57 106 174] 8 patients belonging to this group were confirmed fused though there was no good bony growth visualized on x-rays. Bone fusions in these patients were confirmed by the CT scanogram which shows good union.

Pseudoarthrosis is typically defined as a discontinuous or fibrous interface,[37 39 47 53 174 176] Pseudoarthrosis may be painful or asymptomatic. [52 104 105]However, we have to acknowledge that there is difficulty in assessing solid fusion, in the presence of fixation.[57 102] Two patients were identified, one patient was confirmed on CT scanogram and the other had translational motion > 4mm with pedicle screw breakage. Both these patients had low modified JOA with Hirabayashi improvement scoring (55.6% and 52.1%) and minimal & severe disability according to the Oswestry Low Back Pain Disability Questionnaire (12% and 44%).

Successful results of PLIF for spinal instability with bony defects has been reported by many authors and has been improving with the introduction of rigid posterior instrumentation with pedicle screws.[177-179] We believe that the addition of rigid internal fixation allows for simplification of the interbody grafting technique. SCHNEE[122] had low fusion (90%) rate attributed to osteoporotic bone in peri-menopausal women more than 55 years of age. Fusion rates in adults are variable and suboptimal results have been associated with obesity, osteoporosis, smoking, and systemic illness.[39 57 143 144 150 174 180] In 1993, McGUIRE [174] published the only prospective, randomized study evaluating pedicle screw fixation for adult spondylolisthesis. The fusion rate was greater in patients with fixation however was not statistically significant. In 1994, YUAN and colleagues [56] published a historical cohort study of pedicle screw fixation for degenerative spondylolisthesis in 2684 patients. This revealed a statistically significant increase in rate of fusion in patients treated with pedicle screws 83% vs. 75% in uninstrumented patients. Fusion also occurred more rapidly with fixation. Adding pedicle screw fixation to fusion, RICCIARDI and coworkers[102] reported an increased rate of fusion (94%) for low-grade isthmic listhesis.

Fusion rates for adults with isthmic spondylolisthesis lag behind those of children and adolescents. Fusion rates for children without instrumentation approached 100%,[88] whereas those for adults are 60% to 72%.[116 144] In our study 81% of isthmic listhesis had fusion. 5 spondylolisthesis patients with elongated pars in this study attained fusion, but the number of patient in this group was so small for statistical significance.

There is disagreement in the literature as to whether fusion correlates with clinical outcome in the treatment of lumbar spinal disorders.[122 174] In series specific for spondylolisthesis, a direct relationship between failure to achieve fusion and unsatisfactory pain outcome was reported in both prospective[158] and retrospective [41 42 55 102 116 144 181] studies. However, satisfactory fusion and pain outcomes do not correlate in all series,[39] and even when outcome is satisfactory, return to premorbid employment is not assured.[55 102 144 151] Finally, despite increased fusion rates with the addition of pedicle screw fixation, evidence suggests that factors other than solid fusion markedly influence clinical outcome in patients undergoing operation. [54 55 57 104 150 151 181] These findings suggest that factors other than radiographic fusion significantly influence clinical results. In our study association of graft fusion with the functional outcome was not statistically significant, modified JOA with Hirabayashi improvement scoring (P=0.539) and Oswestry Low Back Pain Disability scoring (P=0.557).

Isthmic listhesis typically presents in younger patients.[105 144 102] KIM et. al.,[70] found that increasing age adversely affected fusion rate in isthmic spondylolisthesis. However, age was not identified as a risk factor for non- union after fusion for isthmic spondylolisthesis by either Hanley and Levy[144] or Ricciardi.[102] Patients with a history of failed fusion are notoriously difficult to treat and carry a substantial risk of persistent pseudoarthrosis, even when pedicle screws are added.[39 52 55 105 175 182] Internal fixation is usually preferred as it is correlated with good clinical outcome after successful arthrodesis in pseudoarthrosis repair. [49 55 70] None of our patients warranted for surgery for pseudoarthrosis repair.

FUNCTIONAL SCORING

The clinical follow-up examinations were performed with The Oswestry Low Back Pain Disability score which is a set of 10 questionnaires mainly assessing the subjective disability for the activities of daily living. Modified JOA with Hirabayashi improvement scoring includes objective assessment with maximum of 20 points as best outcome. The VAS was a 10-cm ruler with which the patients had to rate their pain from pain free of 0 points to intolerable pain of 10 points. Ishihara et al.[146] and Kimura et al.[168] previously demonstrated the correlation between JOA scores and radiological results in spondylolisthesis patients.

In our study at final follow up, mean Oswestry Low Back Pain Disability

Questionnaire score for 31 patients (83.8%) were in mild to moderate disability category with mean score of 18.7% in range of ‘*minimal disability’* (Table 14). The current Oswestry result are substantially better than those reported by Suk et al[69]. But Oswestry scoring being more subjective, 6 patients who did better on the objective scoring both clinically and radiological still had severe disability. Modified JOA with Hirabayashi improvement score of 33 patients (89.2%) were in excellent to good category at final follow up with mean scoring of 70.51% in range of ‘*good’* outcome (Table 13). Other authors have reported JOA results for instrumented PLIF vary from 65%– 76%.[61 183 184]

Analyzing the postoperative lumbar lordosis or slip angle, duration of symptoms with the functional parameters was statistically not significancant (Table 15). The preoperative percentage of listhesis showed a significant association with the functional outcome. Looking at the association of functional outcome with type of listhesis, elongated pars showed better functional outcome compared to isthmic pars in our group.

IMPLANT REMOVAL

Hardware removal has been reported up to 5.4%[122] to 14%[56 151]. The reported indications for implant removal includes, development of painful and tender bursa, chronic back pain, screw prominence, implant failure or elective removal. [56 151] One patient in our study underwent elective implant removal, although the outcome from this is not defined in the literature. Pedicle screw failure may occur in patients who are asymptomatic or have developed pseudoarthrosis[49]. Asymptomatic screw breakage was noted in 3% of our patients, which is comparable to SCHNEE [122]series of 4%. No patients in our study had vascular injuries from screw placement. None of our patients in study died due to the index surgery though 2 patients did not come for follow-up as they expired unrelated to surgery.

CONCLUSIONS

1. Females were at high risk of developing the low dysplastic spondylolisthesis.
2. Younger age group had better functional outcome than the older individual.
3. There was significant improvement in walking distance, which correlated with the functional outcome in these patients.
4. PLIF with pedicle screw fixation, 2 Harms cage and bone grafting used for interbody fusion demonstrated higher fusion rate of 94.6%, markedly influencing clinical outcome in patients.
5. Radiological parameters like degree of sagittal displacement, lumbar lordosis were indicators of good surgical outcome postoperatively.
6. Result of Modified Japanese Orthopaedic Association scoring with Hirabayashi Improvement score of 33 patients (89.2%) showed *'Excellent to good'* outcome, with mean scoring of 70.51% by posterior lumbar interbody fusion surgery in low dysplastic spondylolisthesis.
7. The overall functional assessment by The Oswestry Low Back Pain Disability Questionnaire showed 31 patients (83.8%) with '*minimal to moderate disability'* with mean scoring of *18.7*% following surgery.

8. Adjacent segment disc degeneration is statistically significant association with the functional outcome.
9. Immediate postoperative deep wound infection has no direct bearing on the final outcome when managed immediately and adequately.

STATISTICAL METHODS APPLIED

Two-Related-Samples Nonparametric Tests – was used to assess the relationship between the preoperative and postoperative clinical and radiological parameters. Further the significance was tested by ***Wilcoxon signed-rank test*** which incorporates more information about the data. The Wilcoxon signed-rank test considers information about both the sign of the differences and the magnitude of the differences between pairs.

The Crosstabs' statistics and measures of association are computed for two-way tables only. If you specify a row, a column, and a layer factor (control variable), the Crosstabs procedure forms one panel of associated statistics and measures for each value of the layer factor (or a combination of values for two or more control variables). Chi-square to calculate the ***Pearson chi-square*** and the likelihood-ratio chi-square. When both table variables are quantitative, Chi-square yields the linear-by-linear association test. Used to find the relationship between the functional grading and type of listhesis, gender distribution, age category .

The One-Way ANOVA procedure produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal. This technique is an extension of the two-sample t test. Available multiple comparison tests are ***Bonferroni*** --Once you have determined that differences exist among the means, post hoc range tests and pair wise multiple comparisons can determine which means differ. Range tests identify homogeneous subsets of means that are not different from each other. Pairwise multiple comparisons test the difference between each pair of means and yield a matrix where asterisks indicate significantly different group means at an alpha level of 0.05. Finding the association between the interbody graft fusion with functional scores -Hirabayashi improvement score and Oswestry score, age, VAS scores.

Linear Regression, estimates the coefficients of the linear equation, involving one or more independent variables that best predict the value of the dependent variable. All variables must pass the tolerance criterion to be entered in the equation, regardless of the entry method specified. The default tolerance level is 0.0001. Also, a variable is not entered if it would cause the tolerance of another variable already in the model to drop below the tolerance criterion. Various factors like age, back pain, leg pain, postoperative radiological parameters to affect the functional score and adjacent level degeneration.

Ordinal Regression allows you to adjust parameters used in the iterative estimation algorithm, choose a level of confidence for your parameter estimates, and select a link function. The algorithm stops if the absolute or relative change in the log-likelihood is less than this value. The criterion is not used if 0 is specified. ***Complementary log-log* –** leading to higher categories more probable was used to evaluate the causes to adversely affect the outcome in the severe disability category of Oswestry scoring system.

P =0.05 was considered significant.

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REVIEW OF LITERATURE

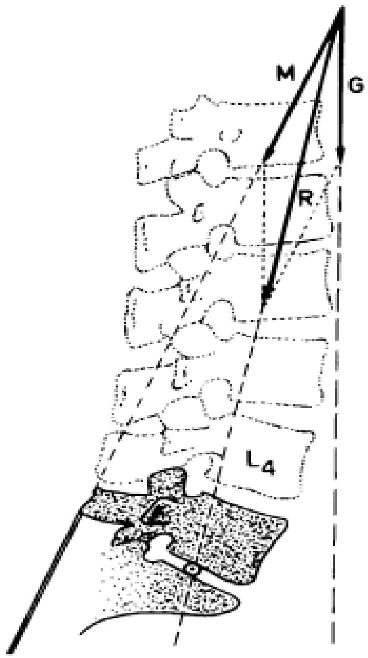


Figure 1

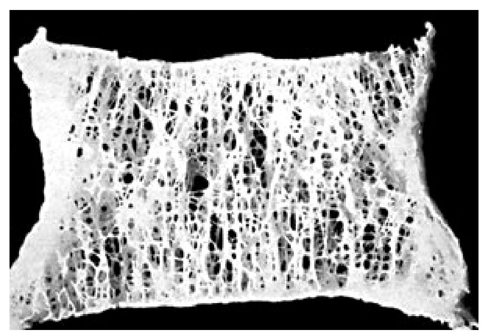
Forces acting on the L5/S1 disc[1]

G = is the body weight to be supported;
M = is the vector of the muscle forces.
R = is the resultant force (the vector sum of G and M)
Note - R strikes the disc from a slanted, ventral direction.

Figure 2

Trabacular pattern

A sagittal section of a lumbar vertebra demonstrates trabeculae perpendicular to the end- plates and not parallel to R



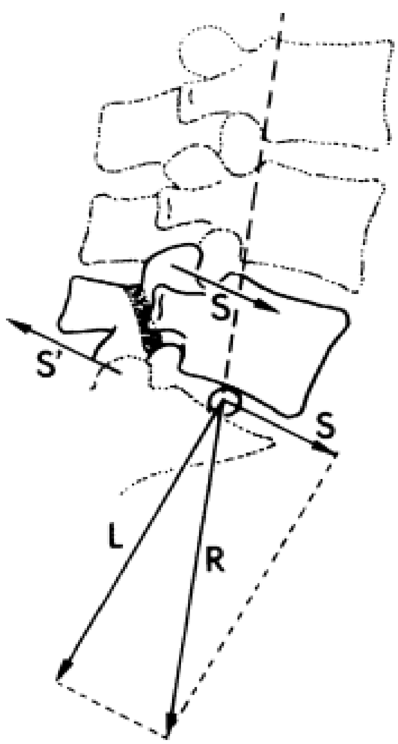


Figure 3

Two components Resultant force R at L5/S1

S = the ventral shifting force

L = the longitudinal force perpendicular to the end-

. plates L5 and SI

s'= the counteracting Force of the facet joints.

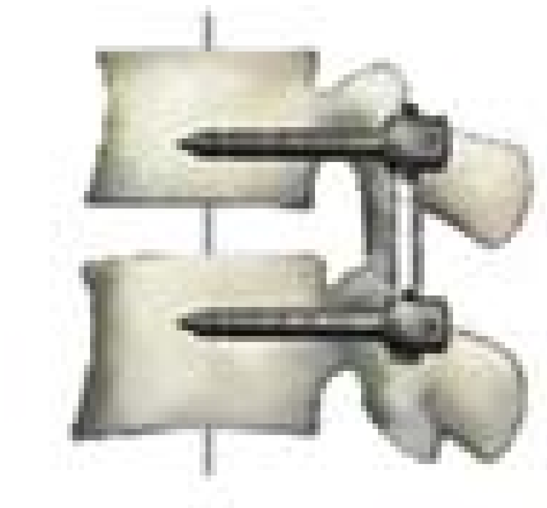


Figure 4 Pedicle screw Fixation

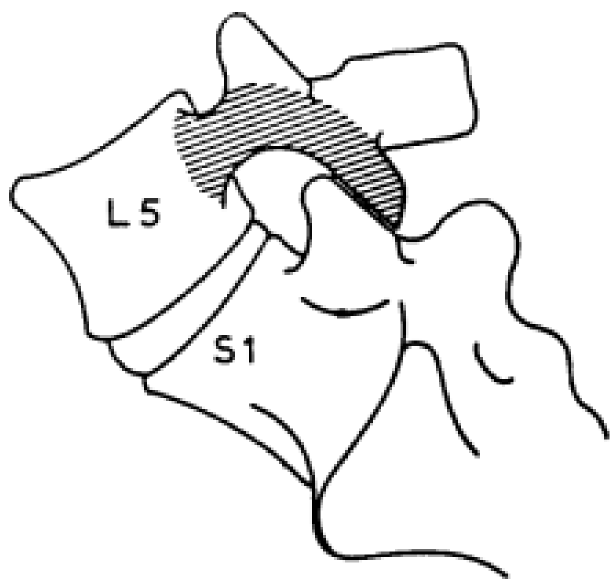


Figure 5 The BONY HOOK

Table 1

WILTSE , NEWMAN, MacNAB [1]

1. DYSPLASTIC
2. ISTHMIC
    a. LYTIC
    b. ELONGATED but intact pars interarticularis
    c. ACUTE FRACTURE of pars interarticularis
3. DEGENERATIVE
4. TRAUMATIC
5. PATHOLOGICAL

Table 2

MARCHETTI –BARTOLOZZI (1982)	
DEVELOPMENTAL	ACQUIRED
• Due to LYSIS • Due to ELONGATION • TRAUMATIC • ACUTE FRACTURE • STRESS FRACTURE	• IATROGENIC • PATHOLOGICAL • DEGENERATIVE

Table 3

MARCHETTI –BARTOLOZZI (1994)	
HIGH DYSPLASTIC • WITH LYSIS • WITHOUT LYSIS LOW DYSPLASTIC • WITH LYSIS • WITHOUT LYSIS TRAUMATIC • ACUTE FRACTURE • STRESS FRACTURE	POST SURGERY • DIRECT SURGERY • INDIRECT SURGERY PATHOLOGICAL • LOCAL PATHOLOGY • SYSTEMIC PAHTOLOGY DEGENERATIVE • PRIMARY • SECONDARY

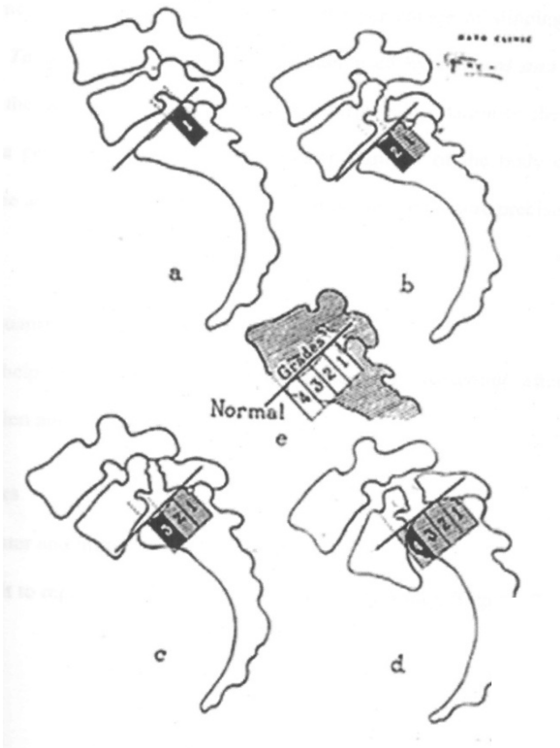
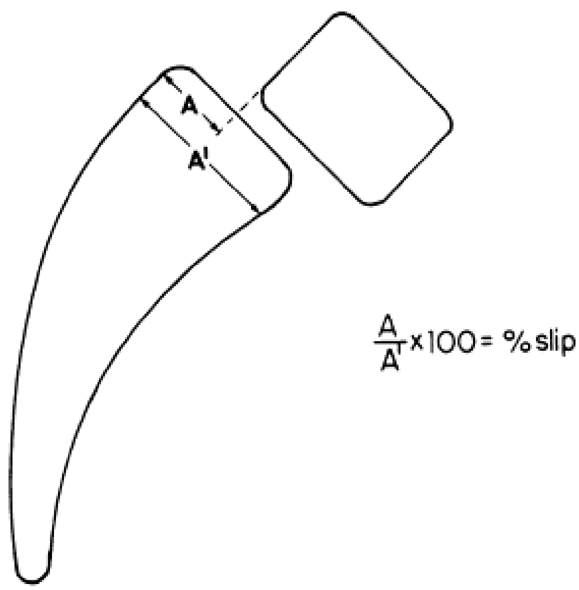


Figure 6

MEYERDING METHOD

Figure 7

TAILLARD'S METHOD



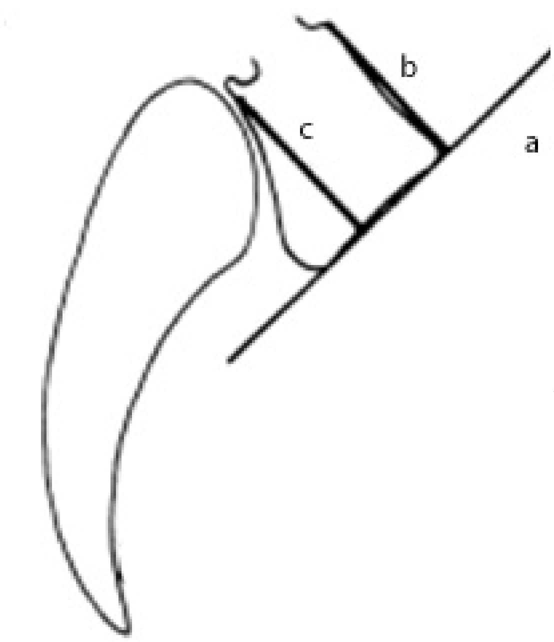


Figure 8

Wiltse method --for correction AP length of L5 vetebrae

Figure 9

NEWMAN'S METHOD

Horizontal measurements as the first number with

Vertical measurements as the second number

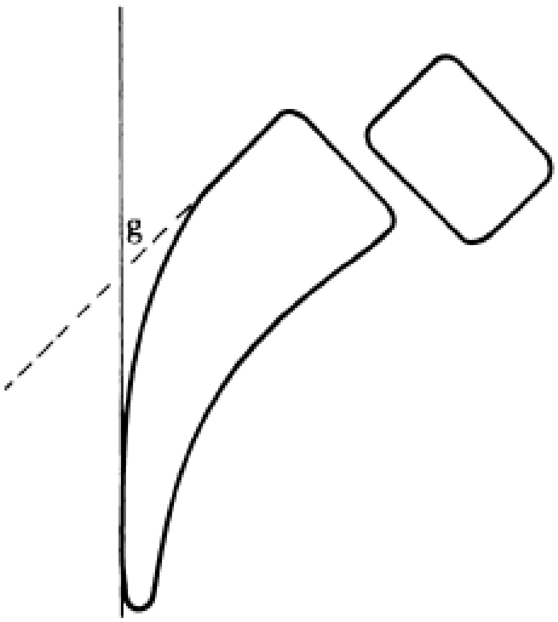


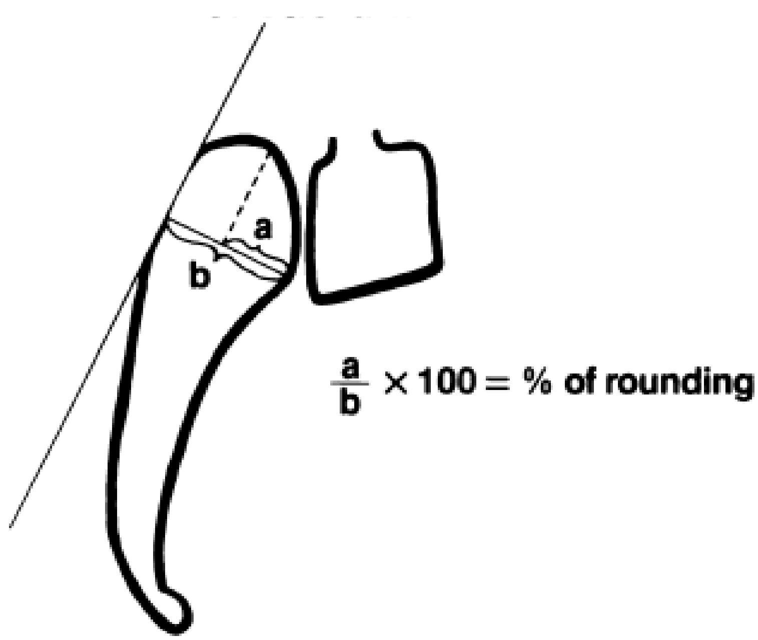
Figure 10

Sacral Inclination

Figure 11

Percentage of Sacral

Rounding



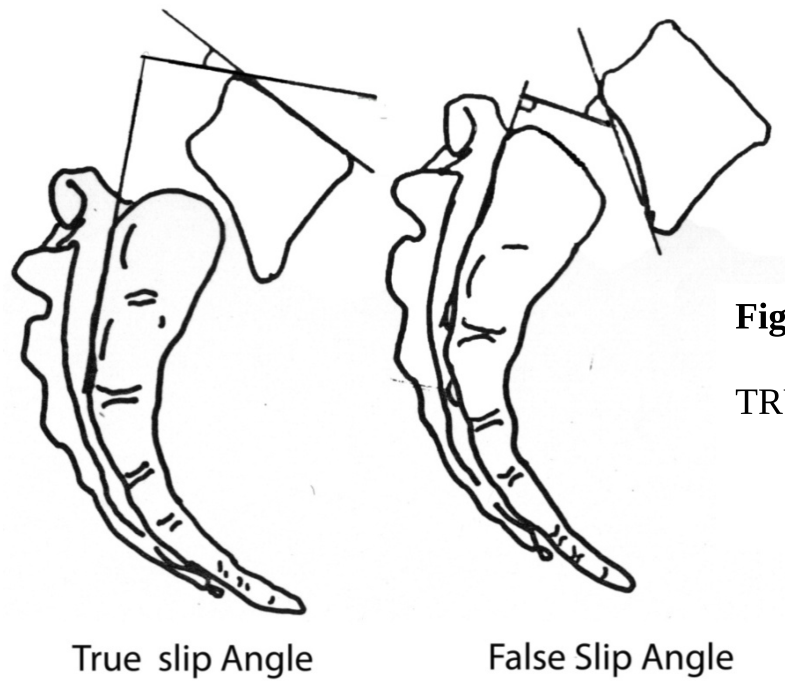


Figure 12

TRUE SLIP ANGLE

Figure 13

Lumbar Lordosis

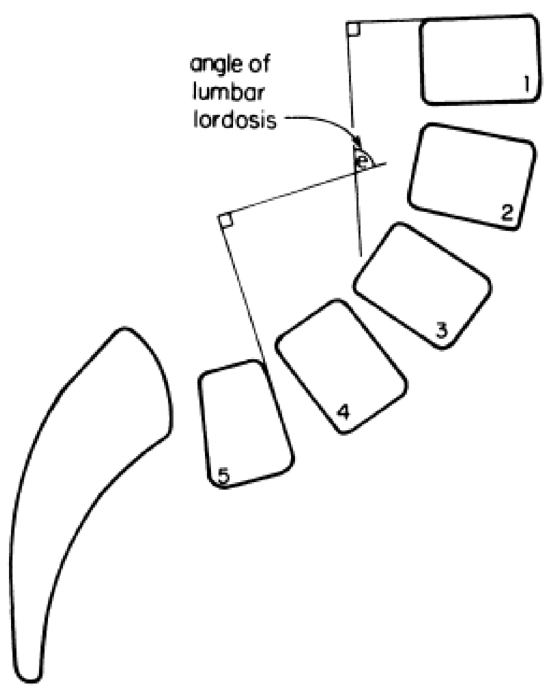
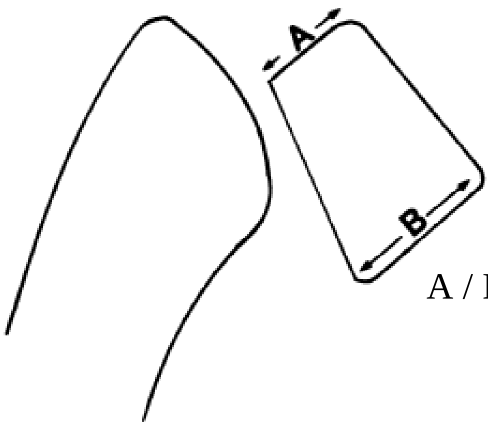


Figure 14

Lumbar Index



A / B x 100

Figure 15

Lumbo Sacral Angle

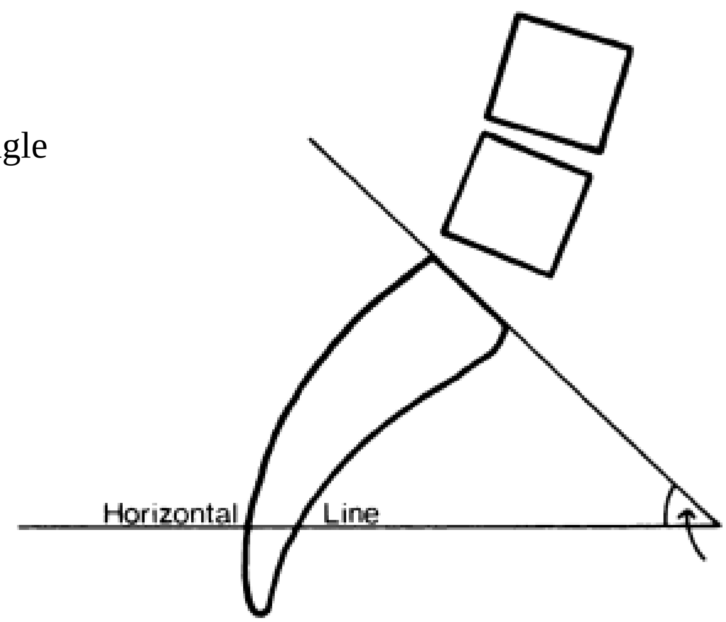


Table 4

Grading	JOA with Hirabayashi improvement scoring
Excellent	75%-100%
Good	50%-75%
Fair	50% - 25%
Poor	25% - 1%

Table 5

INTERPRETATION:

0% to 20%:	*Minimal disability*: The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting sitting and exercise.
21%-40%:	*Moderate disability*: The patient experiences more pain and difficulty with sitting lifting and standing. Travel and social life are more difficult and they may be disabled from work. Personal care sexual activity and sleeping are not grossly affected and the patient can usually be managed by conservative means.
41%-60%:	*Severe disability*. Pain remains the main problem in this group but activities of daily living are affected. These patients require a detailed investigation.
61%-80%:	*Crippled*. Back pain impinges on all aspects of the patient's life. Positive intervention is required.
81%-100%:	*Bed Bound*. These patients are either bed-bound or exaggerating their symptoms.

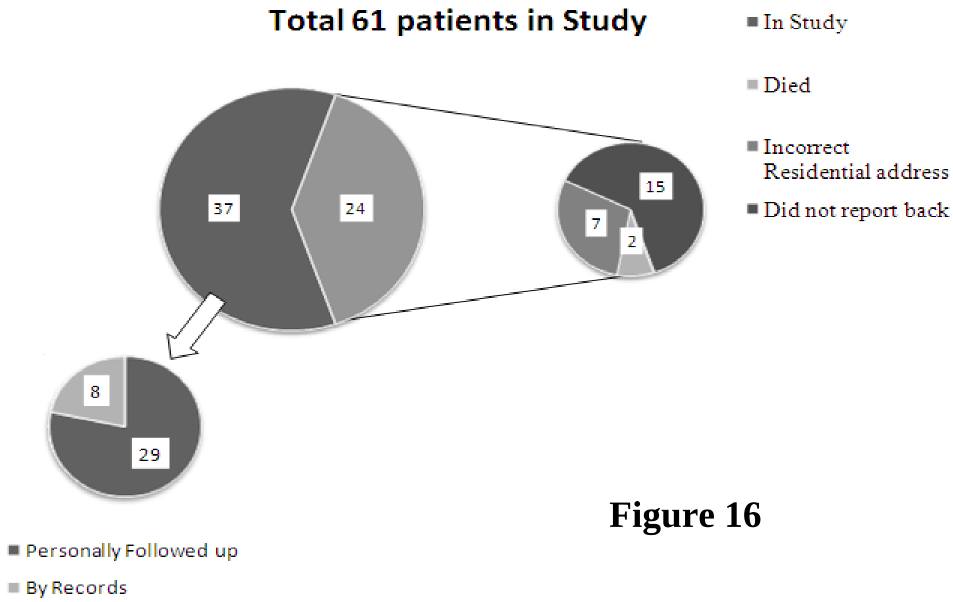
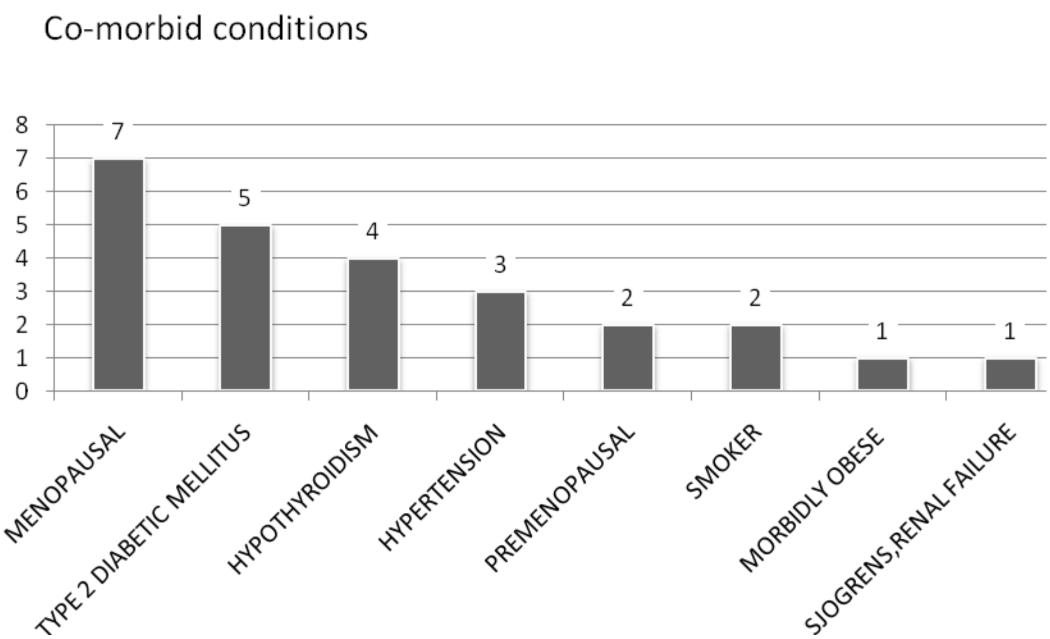

Total 61 patients in Study
In Study
Died
Incorrect Residential address
Did not report back
37
24
15
7
2
8
29
Personally Followed up
By Records

Figure 16

Figure 17


Co-morbid conditions
8
7
6
5
4
3
2
1
0
7
5
4
3
2
2
1
1
MENOPAUSAL
TYPE 2 DIABETIC MELLITUS
HYPOTHYROIDISM
HYPERTENSION
PREMENOPAUSAL
SMOKER
MORBIDLY OBESE
SJOGRENS,RENAL FAILURE

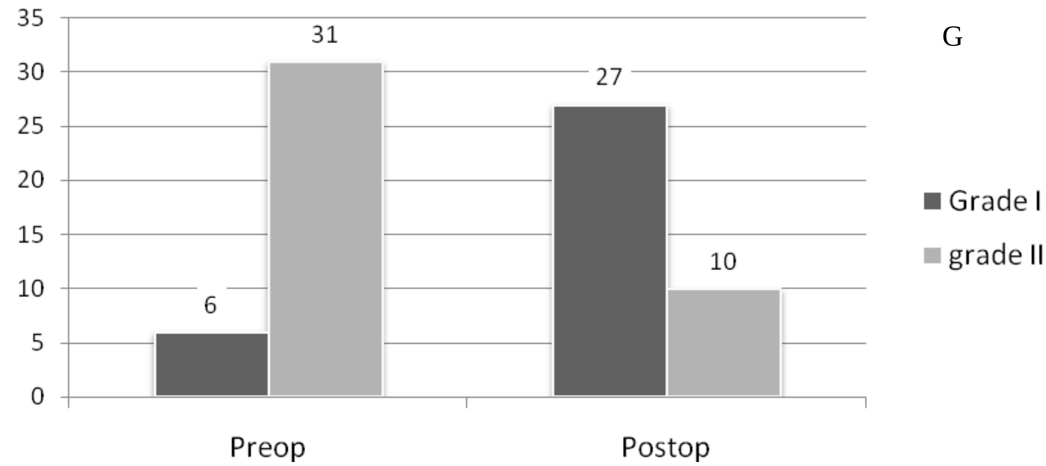


Figure 18

Grade of Listhesis Preoperative and Postoperative

Figure 19

Preoperative Back & Leg Pain Score

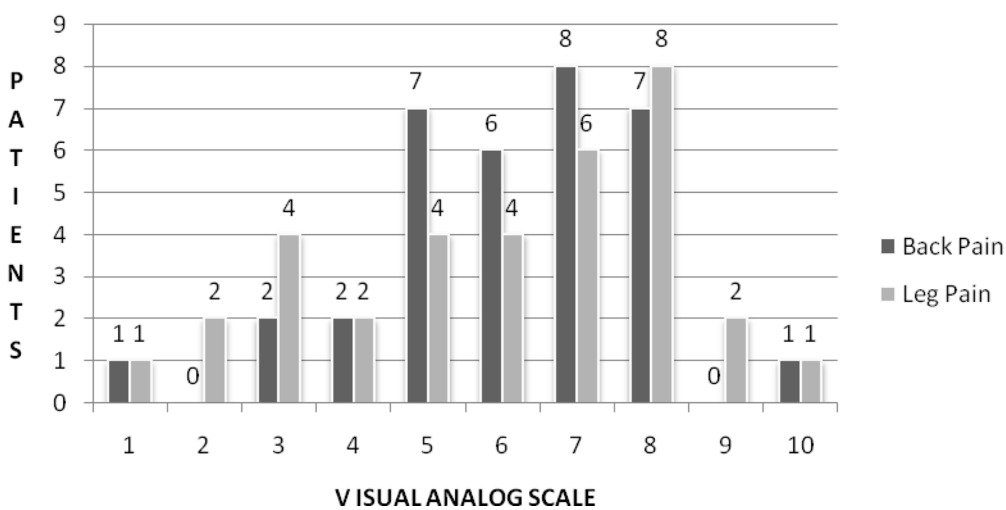


Table 6

Preoperative and Postoperative Motor Deficits

Motor weakness (Extensor Hallucis longus)	Preoperative motor status	Final follow up motor status
Grade 2/5	1 patient	0 patients
Grade 3/5	3 patients	2 patients
Grade 4/5	4 patients	4 patients
Grade 5/5	29 patients	31 patients

Table 7

Paired Samples Statistics for Preoperative and Final Follow up Angles				
Radiological parameters		Mean	Std. Deviation	Significance
Degree of slip (Meyerding)	Preoperative	1.84	0.37	***P=0.000***
	Final Follow-up	1.27	0.45	
Percentage of slip (Taillard)	Preoperative	35^0	0.10	***P=0.000***
	Final Follow-up	22^0	0.12	
Slip Angle	Preoperative	19.82^0	10.37	P=0.318
	Final Follow-up	17.94^0	12.94	
Sacral Inclination	Preoperative	51.62^0	14.94	P=0.107
	Final Follow-up	47.65^0	13.18	
Lumbo-Sacral Angle	Preoperative	40.62^0	17.71	P=0.080
	Final Follow-up	35.39^0	12.42	
Lumbar Lordosis	Preoperative	36.46^0	15.33	***P=0.028***
	Final Follow-up	30.70^0	13.72	
Lumbar index	Preoperative	81^0	0.12	P=0.762
	Final Follow-up	82^0	0.11	

Table 8

Significance with blood loss with various Factors	
Factors	Significance
Age	P=0.978
Gender	P=0.204
Type of listhesis	P=0.545
Degree of listhesis	P=0.164
Interbody fusion	P=0.806
Duration of surgery	P=0.000

Table 9

Significance with Duration of Surgery with various Factors	
Factors	Significance
Type of Listhesis	P=0.700
Degree of listhesis	P=0.231
Fusion of Graft	P=0.894

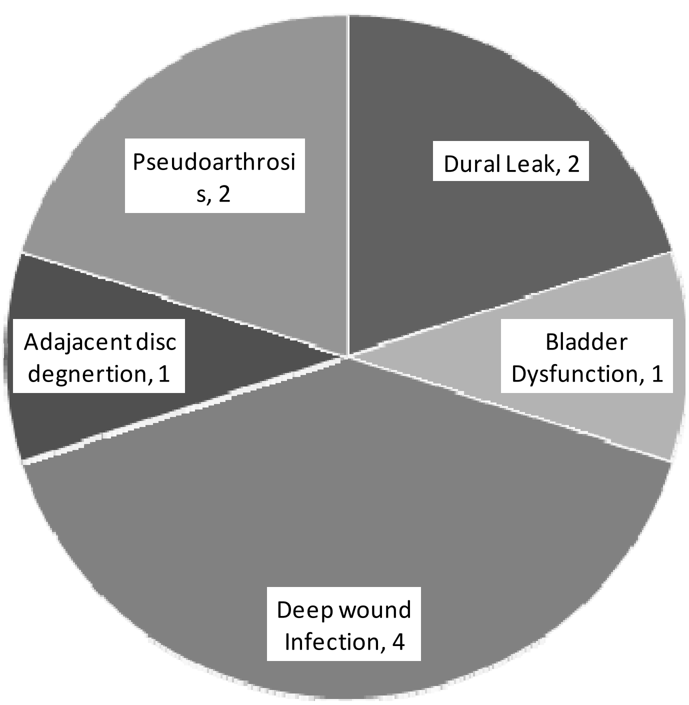


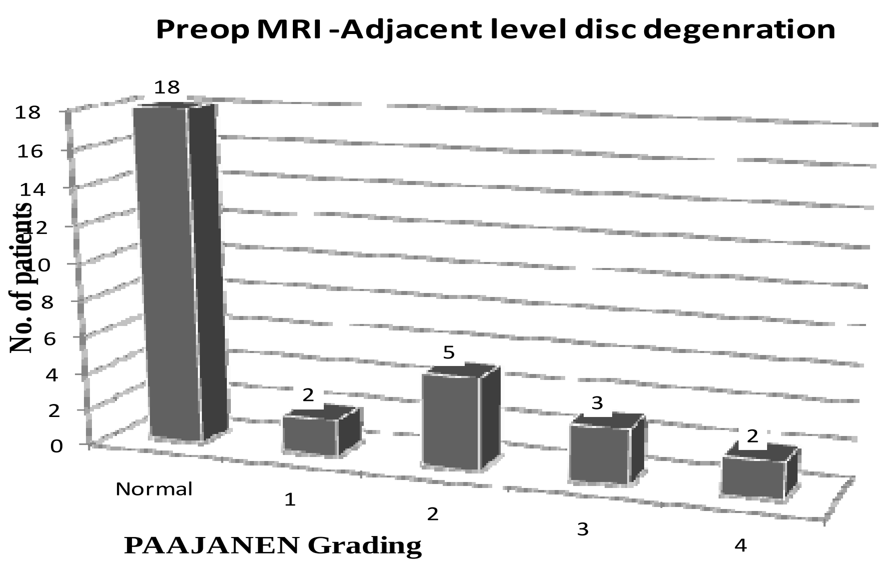
Figure 20

POSTOPERATIVE COMPLICATIONS OF SURGERY

Table 10

Postoperative Deep wound infection with Functional Scoring					
Patients Serial No.	*Final followup Back Pain VAS*	*JOA with Hirabayashi*		*Oswestry Disability*	
		Scoring	*Grading*	*Scoring*	*Disability Grading*
11.	2	61.66%	Good	35.50%	Moderate
20.	1	75.45%	Excellent	15.00%	Mild
24.	2	78.72%	Excellent	20.00%	Mild
35.	0	72.54%	Good	44.00%	Moderate

Figure 21



Preop MRI -Adjacent level disc degenration
18
2
5
3
2
18
16
14
12
10
8
6
4
2
0
No. of patients
Normal
1
2
3
4
PAAJANEN Grading

Table 11

Graft Fusion Status

Graft Fusion Status		No. of patient	Percentage
UNITED	Bony Trabaculae	20	94.6%
	Sentinel Sign	7	
	Functional arthrodesis	8	
NON UNION		2	5.4%
Total		37	100.0

Table 12

INTERBODY FUSION association with AGE						
Age	Bony Trabaculae	Sentinel Sign		Functional Arthodesis	Pseudo-arthorsis	Significance
25 -- 40 years	5	6	11/12	0	1	P= 0.005
41 -- 60 years	15	1	16/22	5	1	
61 --80 years	0	0	0/3	3	0	
Total	20	7	27/37	8	2	

Table 13

Patient Distribution according to Modified JOA Scoring

JOA with Hirabayashi improvement Grading	No. Of Patients
Excellent	23
Good	10

Fair	4
Poor	0

Table 14

Patient distribution according to Oswestry Disability Questionnaire

Oswestry Low Back Pain Disability Questionnaire	INTERPRETATION	No. of patients
0% to 20%	Minimal disability	25
21%-40%	Moderate disability	6
41%-60%	Severe disability	6
61%-80%:	Crippled	0
80% - 100%	Bed ridden.	0

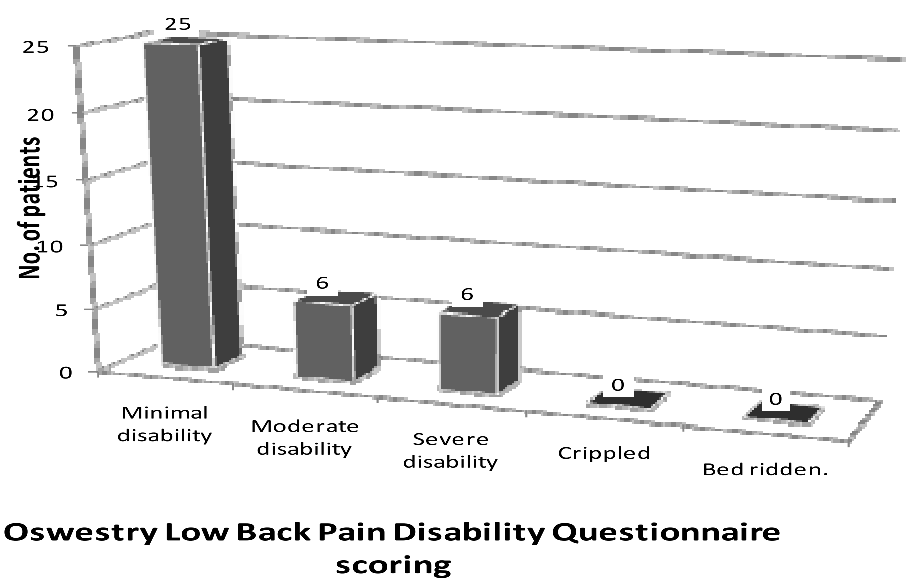


Figure 22

Factors	Oswestry Low Back Pain Disability Questionnaire	JOA scoring	Significance

Duration		P=0.412	P=0.341	Not Significant
Preoperative low back pain		***P=0.012***	***P=0.003***	**Significant**
Preoperative displacement		***P=0.001***	***P=0.032***	**Significant**
slip angle at final followup.		P=0.679	P=0.200	Not Significant
Type	Isthmic	P=7.000	P=4.250	Not Significant
	Elongative	***P=0.000***	***P=0.000***	**Significant**
Postoperative Lumbar Lordosis		P=0.466	P=0.935	Not Significant
Adjacent level disc degeneration		***P=0.028***	***P=0.036***	**Significant**

Table 15

Serial No.	Hospital No.	Age	Gender	Type Listhesis	Follow up Druation months	SurgeryDate	Complication	Co-Morbid	Non Operative	Surgery Duration hrs.	Blood Loss ml.	Hospital Duration days	Preop Back Pain Duration months	Preop Back Pain VAS	Preop Leg Pain Side	Preop Leg Pain Duration	Preop Leg Pain VAS	Preop RestPain	Preop Walk Dist.	Preop Bowel Bladder	Preop List
1	679779C	26	M	E	55	4	0	0	6	4	550	14	36	8	1	12	3	1	500	1	1
2	684831C	34	F	L	52	4	0	6	7	3	350	14	36	5	3	24	6	1	300	1	2
3	427196C	35	F	L	33	6	0	0	4	1	100	14	180	6	5	132	6	1	500	1	3
4	225261C	46	F	L	86	1	1	6	1	2	400	14	48	8	1	12	3	1	250	2	2
5	065890D	46	M	L	29	6	0	5	7	4	600	14	120	6	3	36	8	2	500	1	1
6	683433C	37	M	L	52	4	0	0	2	2	250	14	5	5	2	6	8	1	200	1	1
7	169919C	53	M	L	90	1	0	0	7	6	1200	14	120	4	2	84	7	1	100	1	1
8	315034C	41	F	L	79	2	0	0	0	4	450	14	48	7	3	6	2	1	200	1	1
9	886938C	65	F	L	30	6	0	1	0	4	500	14	120	5	2	48	3	1	500	1	1
10	140113C	45	M	L	81	2	0	0	5	5	400	14	12	7	5	120	4	1	250	1	1
11	454329B	42	F	L	100	0	2	0	2	3	350	18	72	8	5	36	5	1	500	1	2
12	889846C	37	F	L	38	5	0	4	7	2	500	14	180	3		96	6	1	100	1	2
13	044120C	58	F	L	102	0	0	8,4	0	3	300	14	72	7	2	18	7	1	300	1	1
14	889657C	44	F	E	31	6	0	6	8	2	250	14	24	8		6	7	1	500	1	3
15	223266C	56	F	L	74	2	0	6	7	5	1000	14	18	6		6	0	1	500	1	1
16	956927C	49	M	L	35	6	0	4,5	7	3	350	14	120	8	3	12	7	1	500	1	3
17	854228A	44	F	L	38	5	0	0	0	3	200	14	66	3	2	72	9	1	50	1	3
18	368315C	39	F	L	75	2	0	0	0	3	250	14	336		5	60	-	1	50	1	1
19	031085D	37	F	L	31	6	0	0	4	3	250	14	84	7	5	4	8	1	250	1	1
20	493242C	52	F	L	65	3	2	3	5	3	300	29	24	7	2	3	4	1	50	1	3
21	459614C	67	M	L	65	3	1	3,4	0	3	350	14	12	8	1	48	5	1	250	1	2
22	549290C	54	F	L	59	4	0	1	0	3	300	14	12		2	24	10	1	50	2	1
23	206209B	52	F	E	41	5	0	1	0	3	350	14	48	5	4	36	3	1	50	1	3
24	998755C	46	F	L	32	6	2	1	7	5	400	15	240	10	4	24	2	1	50	1	1
25	924576C	67	M	E	37	5	3	0	5	2	200	14	228	5	5	42	5	2	50	1	2
26	760782C	54	F	L	47	5	0	2	0	3	250	14	6	7	5	6	9	1	250	1	3
27	252069C	45	F	L	81	2	0	0	3	5	550	14	180	6	2	120	1	1	350	1	1
28	236235C	41	M	L	86	1	0	0	4	4	600	14	3	1	5	6	5	1	500	1	1
29	223139C	48	F	E	86	1	0	0	3	5	500	14	18	7	5	24	8	1	200	1	1
30	528704C	49	F	L	59	4	0	1	0	3	200	14	120	5	4	12	8	1	500	1	1
31	181787C	34	F	L	89	1	0	7	0	5	800	14	24	7	5	6	7	1	250	2	1
32	250191C	46	F	L	85	1	0	1	0	4	600	14	36	5	1	4	8	1	500	1	3
33	495574C	40	F	L	57	4	0	4	3	3	300	14	60	6	4	36	8	1	500	1	2
34	500821C	40	M	L	63	3	1	0	0	5	750	14	48	6	4	12	6	1	1000	1	3
35	320842C	38	M	L	45	5	2	3	0	3	300	21	60	4	2	36	7	1	1000	1	1
36	779535B	38	F	L	67	3	0	1	0	5	700	14	36	8	1	12	8	1	500	1	1
37	838703C	42	F	L	40	5	0	2	0	3	150	14	144	7	1	36	7	1	200	1	3
				L=Lytic		2001=0	No Compliction = 0	Menopause=1	Traction=1						1 Rt.=Lt.			1= No		1= Normal	1= Lumar Lordosis
				E=Elongative		2002=1	DURAL LEAK= 1	Premenopause=2	Belt =2						2Rt.>Lt.			2=Yes		2=Involved	2=List Rt.
						2003=2	Wound Infection = 2	HTN = 3	Physio=3						3Lt.>Rt.						3=List Lt.
						2004=3	Cauda equina= 3	DM = 4	BP=4						4Rt.						
						2005=4		Smoker = 5	TB=5						5Lt.						
						2006=5		Hypothyroid= 6	TP=6												
						2007=6		Obese = 7	TBP=7												
								SJOGRENS,Renal failure = 8	TBPE=8												

PreopGait	Preop Step	Preop Tenderness	SLR	Preop Motor	Preop Sensory Level	Preop Sensory Percentage	Postop. Back Pain VAS	Postop Leg Pain Side	Postop Leg Pain VAS	Postop Leg Pain Dist. Meters	Postop Bowel Bladder	Postop List	Postop Step	Postop Tenderness	Postop SLR	Postop Motor	Postop Sen Level	Postop Sensory Per.	Preop X Degree	Preop X Per.
1	2	2	1	1	1	25	1	6	1	2500	1	0	2	2	2	1	0	0	1	16.75%
1	1	1	1	1	4	10	1	1	2	2000	1	0	2	2	2	1	4	10	2	44.65%
1	1	1	1	1	0	0	2	6	1	2000	1	0	2	2	2	1	0	0	2	37.31%
1	2	1	1	2	4	50	1	6	1	1000	2	1	2	2	2	2	4	75	2	41.94%
1	2	2	1	1	1	10	1	6	1	2500	1	0	2	1	2	1	1	10	2	50.70%
1	1	2	1	1	2	75	0	6	0	3000	1	0	2	2	2	1	0	0	2	30.24%
1	1	1	1	2	5	25	3	1	3	2000	1	0	2	2	2	1	0	0	2	39.58%
1	1	2	1	1	0	0	0	6	0	3000	1	0	2	2	2	1	0	0	2	43.42%
1	1	2	1	1	0	0	4	6	2	2000	1	0	2	2	2	1	0	0	2	27.47%
1	1	2	1	1	0	0	5	6	2	1500	1	2	2	1	2	1	0	0	2	28.24%
1	2	1	1	2	0	0	2	6	1	1750	1	0	2	2	2	1	0	0	1	20.72%
2	1	2	1	1	2	25	1	6	2	2000	1	0	2	2	2	1	0	0	2	48.57%
1	1	1	1	1	1	10	3	3	2	1000	1	0	2	2	2	1	0	0	1	18.66%
1	1	2	1	1	0	0	5	6	4	2000	1	0	1	2	2	1	0	0	2	28.73%
1	1	1	1	1	0	0	4	6	0	2000	1	0	2	2	2	1	0	0	2	26.38%
1	1	1	1	1	5	25	5	1	0	4000	1	0	2	2	2	1	0	0	2	46.73%
2	1	1	1	1	0	0	4	6	2	3000	1	0	2	2	2	1	0	0	1	21.61%
2	2	1	2	1	1	10	2	6	2	2000	1	0	2	2	2	1	1	10	2	40.23%
2	2	2	1	1	0	0	1	6	3	2000	1	0	2	2	2	1	0	0	2	26.75%
1	1	2	1	1	0	0	1	6	1	750	1	0	2	2	2	1	0	0	2	31.93%
1	2	2	1	1	1	25	1	6	1	2500	1	0	2	2	2	1	0	0	2	34.78%
2	1	1	1	1	0	0	2	6	0	1500	1	0	2	2	2	1	0	0	2	40.42%
2	1	1	1	3	0	0	2	6	3	1000	1	0	2	2	2	2	0	0	2	46.86%
1	2	1	1	1	1	10	2	6	2	2000	1	0	2	2	2	1	0	0	2	33.64%
1	1	2	1	4	3	50	7	5	7	100	2	0	2	1	2	3	3	75	1	23.11%
2	2	1	1	1	0	0	4	6	1	2000	1	0	2	2	2	1	0	0	2	33.92%
1	2	2	1	1	0	0	3	6	1	1500	1	0	2	2	2	1	0	0	1	18.22%
1	1	1	1	1	0	0	0	6	0	2500	1	0	2	2	2	1	0	0	2	50.50%
1	1	1	1	1	0	0	1	6	0	2000	1	0	2	2	2	1	0	0	2	33.34%
1	1	1	1	1	0	0	4	6	5	1000	1	0	2	2	2	1	0	0	2	37.35%
1	1	1	1	2	5	25	1	1	2	2000	1	0	2	2	2	2	0	0	2	45.40%
1	1	1	1	1	0	0	2	6	0	4000	1	0	2	2	2	1	0	0	2	38.65%
1	1	2	2	1	0	0	2	6	1	2500	1	0	2	2	2	1	0	0	2	33.80%
1	1	1	1	3	1	50	5	4	4	500	1	0	2	1	2	1	0	0	2	30.44%
1	1	2	1	1	0	0	0	4	2	3000	1	0	2	2	2	1	0	0	2	39.59%
1	1	1	1	3	1	50	3	4	2	750	1	0	2	2	2	1	0	0	2	42.50%
1	1	2	1	1	0	0	0	1	1	2000	1	0	2	2	2	1	0	0	2	34.01%
1 NOR	1 = Yes	1 = Yes	1 = Yes	1-5/5	L5 = 1			1 Rt.=Lt.			1= Normal	1= Lumar Lordosis	1 = Yes	1 = Yes	1 = Yes	1/5/1905	L5 = 1			
2STIFF	2= No	2= No	2= No	2-4/5	S1 = 2			2Rt.>Lt.			2=Involved	2=List Rt.	2= No	2= No	2= No	2/4/1905	S1 = 2			
				3-3/5	L4,5 =3			3Lt.>Rt.				3=List Lt.				3/3/1905	L4,5 =3			
				4-2/5	L5,S1= 4			4Rt.				0=Normal				4/2/1905	L5,S1= 4			
					L4,5,S1= 5			5Lt.									L4,5,S1= 5			
								6= Normal									4,5,1 5			

Preop X Slip angle	Preop X Lumbar Index	Preop X Sacral Inclination	Preop X Sacral Round	Preop X Lumbar Lordosis	Preop X Lumbo Sacral angle	Postop X Deg.	Postop X Per.	Immediate Postop X Per.	Postop X Slip angle	Postop X Lumbar Lordsis	Postop X Sacral Inclination	Postop X Lumbar Lordosis	Postop X Lumbo Sacral angle	Postop X Fusion Status	Preop MRI level	Preop MRI Adjacent Level	Postop JOA	Preop JOA	Hirabiashi score %	Oswestry score %
28.50	0.89	59.30	0.47	19.80	1.00	1	13.00%	0.13	11.80	0.94	50.90	29.3	0	2	2	1	19	6	92.86	22.50%
22.50	0.53	25.10	0.49	23.90	16.10	2	38.46%	0.38	22.00	0.78	40.00	28	2	2	1	1	15	4	68.75	12.00%
31.20	0.76	27.20	0.41	34.30	18.70	1	24.36%	0.24	33.30	0.81	28.10	32	6.8	1	2	1	18	3	88.24	13.30%
3.40	0.85	58.50	0.48	60.60	4.00	2	29.64%	0.30	7. 3	0.94	62. 6	48.2	1.6	1	2	1	16	4	75.14	18.00%
8.60	0.69	39.80	0.15	54.70	34.00	2	46.17%	0.46	3.20	0.68	29.00	46.1	0.3	3	2	1	17	6	78.57	2.00%
16.90	0.45	34.70	0.42	32.80	3.80	1	16.67%	0.17	20	0.39	49.00	28	5	1	1	1	18	8	83.33	6.00%
25.70	0.63	61.60	0.60	47.60	5.80	1	19.33%	0.19	18.90	0.80	57.20	31	8.4	3	2	1	17	6	78.57	6.00%
15.40	0.85	75.50	0.42	43.30	0.60	1	1.00%	0.01	9.10	0.85	64.30	35.9	0.5	1	2	1	19	4	93.75	0.00%
2.10	0.90	80.70	0.37	52.90	17.60	1	22.74%	0.23	1.20	0.80	51.50	24.1	4.5	3	2	3	13	7	46.15	53.33%
29.60	0.88	63.80	0.44	42.20	37.60	1	24.21%	0.24	13.50	0.83	28.00	19.7	4.6	1	1	2	13	7	46.15	15.56%
11.90	0.82	53.40	0.48	49.00	8.20	1	1.00%	0.01	19.60	0.90	59.60	43.3	6.5	1	3	3	13	6	49.85	35.50%
27.80	0.73	58.70	0.33	63.90	31.40	1	22.13%	0.22	22.40	0.73	44.00	47.2	11.4	1	3	1	18	5	86.67	5.00%
1.10	0.75	39.60	0.46	59.30	10.60	1	17.33%	0.17	12.00	0.89	67.00	36.3	9.5	3	1	3	11	7	30.77	51.11%
35.40	0.80	36.40	0.54	52.10	13.30	2	31.59%	0.28	25.50	0.80	35.50	12.5	7.1	1	2	1	11	6	35.71	42.22%
31.90	0.82	58.30	0.40	38.20	13.90	2	27.21%	0.25	17.80	0.77	57.80	15	6.3	1	3	1	16	4	75.52	22.20%
21.80	0.87	27.10	0.00	9.20	7.60	1	1.00%	0.01	17.60	0.94	28.60	14.2	1.4	3	1	1	16	8	66.67	22.22%
1.10	0.94	56.80	0.50	13.80	1.80	1	13.60%	0.14	6.40	0.61	45.50	7.4	1.5	1	1	2	17	9	72.73	20.00%
35.60	0.87	55.00	0.23	35.70	22.30	1	22.72%	0.23	20.00	0.80	36.00	49	7	1	2	2	18	9	80.34	0.00%
15.00	0.88	65.80	0.29	50.50	55.00	1	18.00%	0.18	6.00	0.93	32.00	40	4.4	2	2	1	16	3	76.47	6.67%
22.70	0.85	27.60	0.45	32.90	0.30	1	11.63%	0.12	9.26	0.72	27.05	36.88	0.5	1	1	1	16	3	76.47	15.00%
12.60	0.74	39.40	0.21	52.80	7.10	1	10.60%	0.11	6.30	0.73	58.00	48.2	6.8	3	1	1	19	3	94.12	2.50%
35.20	0.88	81.70	0.52	17.80	4.20	1	17.08%	0.17	21.70	0.91	70.00	15.5	1.1	1	1	1	16	4	75.00	6.78%
6.00	0.78	47.70	0.40	38.80	10.30	1	20.15%	0.20	3.80	0.91	57.50	49.1	3.6	1	1	1	17	6	78.57	4.40%
23.10	0.85	53.80	0.32	4.50	3.60	2	42.99%	0.34	35.70	0.74	54.60	10.30	7.50	1	2	1	17	6	78.57	20.00%
5.00	0.82	47.30	0.47	39.80	1.80	1	14.90%	0.15	1.50	0.89	49.20	32.9	1.5	3	1	4	9	5	26.67	55.56%
32.70	0.76	49.60	0.54	31.50	21.60	1	22.06%	0.22	21.00	0.87	51. 8	25.5	8.7	3	2	1	18	3	88.24	11.00%
32.70	0.73	58.80	0.30	40.90	10.30	2	43.90%	0.18	73.00	0.82	32.00	47	1.1	4	2	1	15	9	54.55	12.00%
11.60	0.65	60.70	0.38	48.60	1.50	2	27.47%	0.27	27.00	0.67	46.80	21.4	6.8	1	2	1	19	3	94.12	0.00%
22.30	0.93	34.30	0.41	38.90	9.20	1	5.58%	0.06	23.9	0.81	37.8	44.8	2.6	1	1	1	15	3	70.59	8.00%
20.10	0.87	45.80	0.47	40.50	21.20	2	39.89%	0.37	16.90	0.92	42.50	41.7	12.9	2	1	1	14	7	53.85	35.56%
20.30	0.77	48.00	0.49	29.40	1.20	1	14.33%	0.14	26.70	0.83	55.50	7.1	7.2	2	2	2	19	9	90.91	14.00%
6.80	0.94	70.60	0.58	16.50	6.50	1	23.40%	0.23	1.90	0.92	77.20	44	5.4	1	1	1	18	9	81.82	11.11%
18.10	0.95	44.40	0.28	13.40	1.00	1	8.72%	0.09	24.70	0.85	42.30	25.5	4.6	1	1	1	17	6	78.57	16.00%
9.60	0.92	52.60	0.33	12.80	5.00	1	22.73%	0.23	18.90	0.73	58.80	41.8	2.6	2	2	1	17	7	76.92	40.00%
24.40	0.91	49.40	0.19	28.9	12.2	1	22.13%	0.22	21	0.83	46.3	4.2	9.9	4	1	1	17	13	57.14	44.00%
22.80	0.77	64.40	0.53	39.50	16.90	2	45.19%	0.44	14.00	0.87	60.80	19.8	5.6	2	2	2	14	4	62.50	22.00%
25.40	0.99	61.30	0.29	37.70	17.50	1	16.99%	0.17	18.20	0.98	47.30	33	1.8	1	1	4	15	11	44.44	20.00%
														United=1	4-5 =1	Normal =1				
														Sentinel =2	5-1=2	Grade2=2				
														Fun.Arthodesis =3	4-5,5-1:	Gradee=3				
														Pseudo=4		Grade4=4				